A GIS-BASED APPROACH FOR THE DETERMINATION OF SERVICE LEVEL AGREEMENT (SLA) ON THE TRANSPORTATION NETWORK: A CASE STUDY OF GAS STATIONS IN BANGKOK METROPOLITAN REGION

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ABSTRACT

Standard consistency and reliability of service quality are key success factors in business. Nowadays, several organizations guarantee their services. However, when organizations advertise such a service level to the customers, it is not known how they set up their service level agreement (SLA). Thus, the purpose of this study is to present a methodology to determine the SLA by using Geographic Information Systems (GIS), simulation techniques, and statistical methods. This method was applied to determine the SLA of gas stations in the Bangkok Metropolitan Region (BMR), as a case study. The results showed that the number of gas stations has affected the SLA in term of accessibility. In addition, the results provided the calculated upper-bound SLA of individual gasoline brands. The proposed method can also be applied to any other businesses to which the service level agreement affects their competiveness.

KEY WORDS: SERVICE LEVEL AGREEMENT / NETWORK ANALYST / GEOGRAPHIC INFORMATION SYSTEM / GAS STATION / SIMULATION

104 Pages

การประเมินระดับการให้บริการบนโครงข่ายคมนาคมขนส่งโดยการใช้ระบบสารสนเทศภูมิศาสตร์และการจำลองสถานการณ์: กรณีศึกษา สถานีบริการน้ำมัน ในพื้นที่กรุงเทพมหานครและปริมณฑล

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บทคัดย่อ

คุณภาพการให้บริการที่ได้มาตรฐาน สม่ำเสมอและเชื่อถือได้ ถือว่าเป็นสิ่งที่สำคัญมากในการทำธุรกิจ ปัจจุบันจะเห็นได้ว่าองค์กรที่เกี่ยวข้องกับการให้บริการ มีการบอกถึงระดับการให้บริการไว้เป็นเงื่อนไขรับประกันคุณภาพ หรือที่เรียกว่า Service Level Agreement (SLA) แต่ตัวเลขที่องค์กรได้โฆษณาไว้ให้กับลูกค้าได้รับทราบนั้นไม่ปรากฏแน่ชัดว่ามีที่มาที่ไปอย่างไร งานวิจัยนี้จึงได้เสนอวิธีการประเมินระดับให้บริการโดยใช้กรณีศึกษาของสถานีบริการน้ำมันซึ่งมีโครงข่ายถนนเข้ามาเกี่ยวข้องอาศัยเทคโนโลยีระบบสารสนเทศภูมิศาสตร์ การจำลองสถานการณ์ร่วมกับวิธีการทางสถิติเป็นเครื่องมือในการวิเคราะห์ โดยทำการทดลองสุ่มลูกค้าจำนวนมากเพื่อทำการประเมินระดับการให้บริการในแง่ของระยะทางจากลูกค้าแต่ละรายไปยังสถานีบริการน้ำมันที่ใกล้ที่สุด นอกจากนี้ยังวิเคราะห์จำแนกระดับการให้บริการสำหรับน้ำมันแต่ละยี่ห้อและทุกยี่ห้อในเขตพื้นที่กรุงเทพมหานครและปริมณฑล

ผลการศึกษาพบว่า จำนวนสถานีบริการมีผลต่อการเข้าถึงของลูกค้า อีกทั้งทำให้ทราบได้ว่าน้ำมันแต่ละยี่ห้อนั้นสามารถให้คำมั่นสัญญาด้านคุณภาพการให้บริการต่อลูกค้าได้ ณ ระดับความเชื่อมั่นต่างๆ ซึ่งช่วยประเมินได้ว่าสถานีบริการน้ำมันแต่ละยี่ห้อนั้นมีความได้เปรียบทางการแข่งขันแตกต่างกันอย่างไร วิธีการที่เสนอในสารนิพนธ์นี้สามารถนำไปประยุกต์ใช้ได้ในธุรกิจอื่นๆ มากมายอันถือว่าเป็นประโยชน์อย่างสูง

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CHAPTER I
INTRODUCTION

1.1 Background and Statement of Problems

Because of the extended environment and economic, it leads to much more business competition, that is, many companies always develop their product for being one part of market share. Moreover, the company has to have the outstanding strategy in the terms of company and goods for making the difference or looking for having advantage over other competitors in the same market or competition. To make the advantage to the company over the competitors, it has to have the efficiency and effect on administration and management in every part of business (Tangjitcharoenpanich, 2005). Especially, the business which is related to the service, it is necessary to develop the service continuously for leading to customers' impression.

Creating the service impression is difficult, because the need of each people is not identical. Thus, each organization has to study the level of customers' satisfaction for finding out the level that the customers accept. Some companies have the punishment to the staff in the case that they cannot provide the service according to the condition that used to promise to the customers. Nowadays, there are a lot of service businesses that adopt the Service Level Agreement (SLA) to be used for the condition of giving service between the company and customers.

SLA is a measure of the effectiveness of services. The result will show as number. It can be analyzed and evaluated. SLA informs customers about the service performance of the company.

Hence, the researcher has the idea about the way of estimating the service level by using the statistical concept together with Geographic Information System technology (GIS). This study estimates the SLA by using the case study of the gas stations as the data in this research. This data include the road network that the GIS can be applied to analyze as well. This research will establish the customers' locations by randomization and then complete the shortest distance to the nearest gas station in the terms of the distance in giving service from the nearest gas station, that is, to categorize into each brand in the area of Bangkok metropolitan region. The strategy and statistical analysis will show about how much the gas station from each brand can have the SLA to the customers. Besides, there is the comparison on other gas stations in the case of how difference of having the advantage over others for being the useful data, and being able to be the reference that will lead to the respect continually.

1.2 Objectives

This research is aimed to accomplish the following two main objectives:

1) To study about the service level agreement of accessibility to locations on the transportation network by using GIS and the principle of statistics.

2) To apply the knowledge in 1) to determine the SLA for a case study of gas station in Bangkok metropolitan region.

1.3 Scope of the Study

This research identifies the scope of the study as follows:

1) To make use of the foundation data (Transportation Fundamental Geographic Data Set: Transport FGDS) (Ministry of Transport, 2007) which is collected and some data is edited to be suitable with this research.

2) SLA of accessibility on the transportation network is measured by the distance to the nearest gas station from a randomized customer.

3) The locations of customers are randomly generated by the computer.

4) The Boundary of the study area is consisted of Bangkok, Nonthaburi, Pathumthani and Samutprakan as shown in Figure 1.1

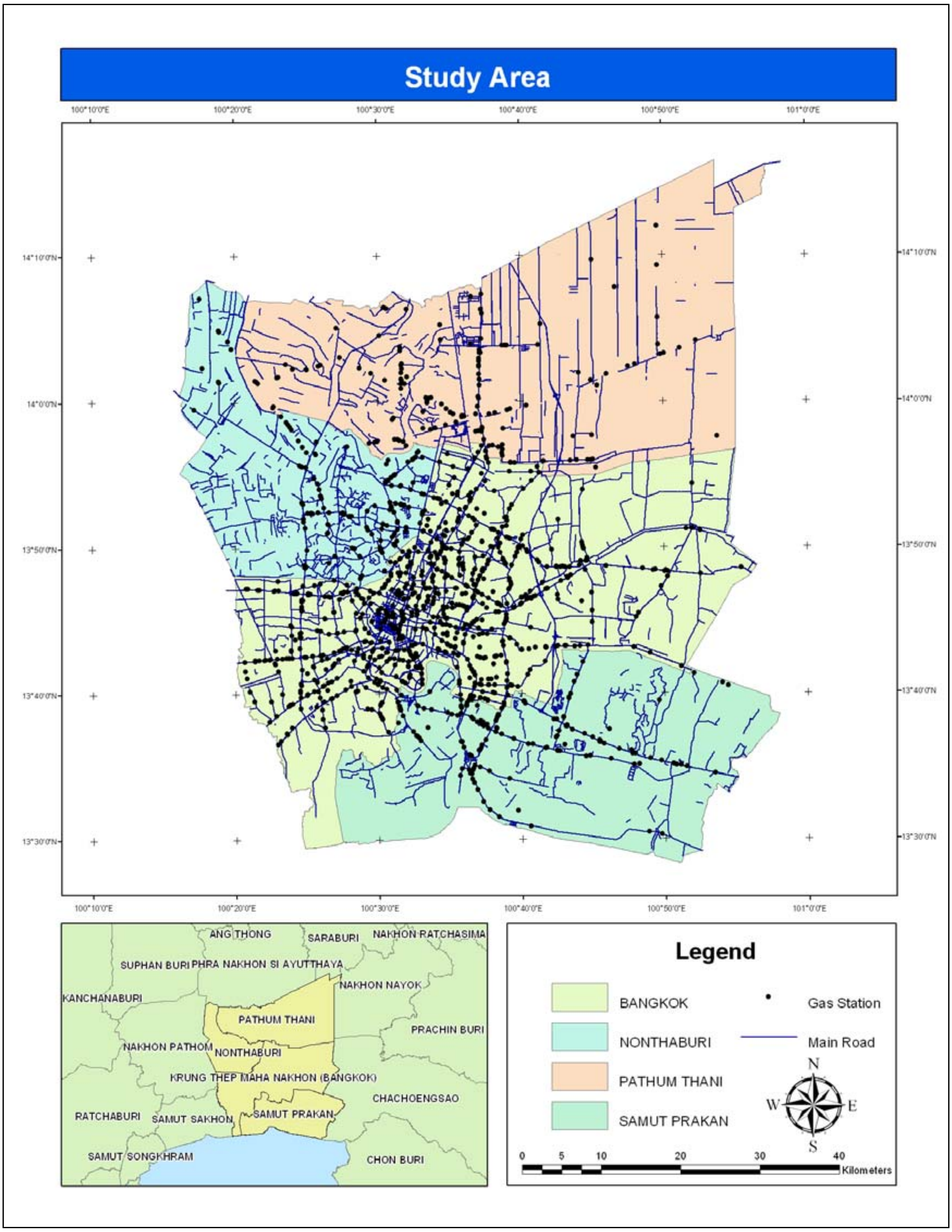

Figure 1.1 The boundary of the study area

1.4 Expected Results

This research utilities GIS and applies the principle of statistics and probability to determine the SLA of accessibility to gas stations. The result of study is to bring up an idea and applicable analytical methods which are useful in several cases such as:

1) The petroleum companies can use the results as a baseline data refer to the service level of their network as well as their competitors.

2) Can have a guideline for improving their service network efficiently.

3) When the petroleum companies' business strategies may be devised based on these results.

4) The results can be also applied to other businesses such as Automated Teller Machine (ATM), postbox, convenient store, banking, etc.

Thus, to make this research have more quality, it is necessary to review related literature thoroughly. This is the contents in the next chapter.

CHAPTER II
LITERATURE REVIEW

This research aims to study how to evaluate the Service Level Agreement (SLA) on accessibility of gasoline stations. SLA is determined in term of distance on the transportation network by means of statistic and probability principle based on a case study. Also, Transport Fundamental Geographic Data Set is used in this research for road networks analyst in condition of the number of customers and number of gas stations. Literature Review is divided into 2 parts as follows:

2.1 Service Level Agreement (SLA)

Service Level Agreement (SLA) may have valid several definitions. In fact, it is deceptively simple. All of the following definitions are significant:

- A service level agreement (SLA) is an agreement between the provider of a service and its customers which quantifies the minimum quality of service which meets the business need. (Hiles, 1994)
- SLAs are essentially informal contracts between the provider of a service and the user of that service. Their purpose is to define the performance required of the service and to put in place measurement mechanisms whereby actual performance against targets can be monitored. (Parish, 1997)

Service level agreement (SLA) is a contract or an agreement of service level between providers and clients in order to make an agreement into the same direction as decided. This agreement needs to be approved by two parties. However, as a reason of different level of each client needs, it needs to be negotiated to find appropriate and accepted levels. As in the Figure 2.1 that show the agreement between providers and clients, in the agreement is consisted of understanding agreement which the two parties already acknowledge such as an ability to service agreement, responsibility agreement etc.

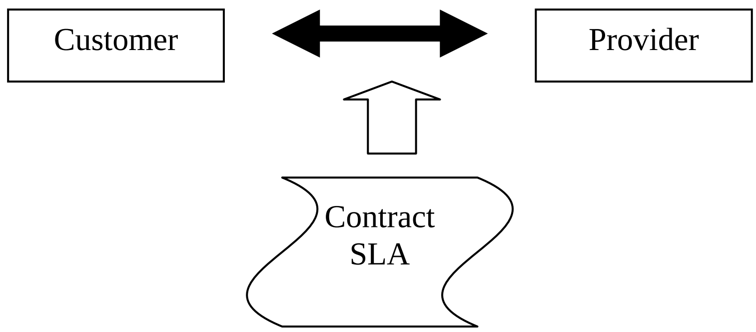

Figure 2.1 An agreement of service level between providers and client (Lee and Ben-Natan, 2002)

Service level agreements were first appeared in 1990 in the Information Technology (IT) unit in the company that provides service of IT for the purpose of measuring their service level and managing Quality of Service (QoS) of computer network system in the company to check how much efficiency there were in order to transferring data to company's customers to comply with company standard. Nowadays, SLA is brought in wide spread to use with goods and services. Providers need to have a standard service that makes clients satisfy within the agreement that the two parties had made together. (Bissel, 2000) Normally, SLA is used in organization that has communication operation between organization and clients for instance; Call Center, Help Desk etc. (Level three support for support service in 2001, 2001) Besides the services which involve with IT business, SLA can also adjust to use with other businesses such as manufacturing business, transportation business etc. SLA is being brought in to the manufacturing business as to use between manufacturer and suppliers of raw material. In transportation business, SLA is used between clients and shipping company. These two cases show the way of bringing SLA to designate the quality of service to become steady which will bring impression to customers. Usually, there will be a legal punishment written down in the agreement, if the company cannot follow the rules.

The most important indicator of service business is time, which is generally called Operational Level Agreement (OLA). It means time in each activity that the company uses for servicing customer in each operation is the time which company commits with customers that they will be serviced within designated SLA time. Thus, the company must designate SLA from customer's perspective and customer's needs. For instance, The company who is good at service standard like McDonald, they specified SLA for customer that every time the customer order foods, they must not be waited less than 60 seconds and this is McDonald's SLA. If we look deeply into their process of work, it certainly designates standard of work and OLA. So, this will impact on customers in a good way which the customer will not wait for long time and also on their business which they can support more customers than any other shops. Besides, they can sell more during the same business hours as other shops. There are other business examples. The sky train will arrive at platform every 5 minutes during rush hour. A new SIM card can be activated within 2 hours when customer first buys it. In the hospital, patients may be told that they should be able to see the doctors or wait for medical fee payment no longer than 15 minutes (Pipatphokakul, 2005). In the duration of servicing customer, there are 2 portions of time (Pipatphokakul, 2006).

1) Service time is the time that company uses for servicing each customer by using SLA as an important criterion which will inform that if the services are good or bad. For instance, when the customer takes the car to the service center for repairing and the service center can inform the customer immediately that it will take around 1 hour to repair. In the case that patient goes to the hospital to see the doctor, the hospital can inform patient that it will take less than 1 hour for all the services from the beginning which is register, measuring pressure, see doctor, pay bill until receive medicines.

2) Waiting time is the time that customers spend to wait for their services. These service operations mostly do not set the limitation on waiting time. However because of the limitation in business investment, company cannot make highly investment for reducing customer waiting time. Therefore, the popular way to use is to make the customer feels good or relaxed while they are waiting. At a bank teller of each branch for example, the last working day of each month, the bank will always have a lot of customers so they must be on a waiting line for a long time. In some branch, customers may have to wait for more than 30 queues or longer than 1 hour. If the bank invests more 5 tellers, the bank will have to pay for more decorations and recruitment. Instead of paying for those, the bank uses the way of making customers

feel good and relaxed by installing a television, having newspapers or magazines, serving water for customers to drink then the customer will not be frustrated while they are waiting. However, it depends on each bank's creativity to choose their extra services to make the customer satisfy.

From the picture of the company that has a service standard; Company will always standardize the services and continue to maintain service levels in order to have the customer receive service standard every time and everywhere. The company must upgrade their standard of service when need of customer changes in order to satisfy to customers and continue their service to compete with the competitors.

While the fundamental principle on quality assessment of services that individual customers may have different expectation on the same product or service, the levels of their expectation affect their satisfaction. Manufacturers or businesses may produce products or provide services that differ from their expectation, which can be higher or lower. In case that the product meets or is beyond their expectation, they would judge that product as a high quality one. But if the product does not meet their expectation, it would become a poor quality product in their opinion. Thus levels of quality of products or services are influenced by levels of difference between products and customers' expectation. Figure 2.2 represents such principle. What customers expect from manufacturers or service providers is called desirable condition, while what they truly receive from manufacturers or service providers is called perceived condition. Quality of products or services can be assessed by evaluating differences between desirable condition and perceived condition (Joseph and Blanton, 2000).

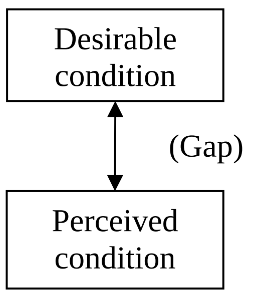

Figure 2.2 Basic concept of Service's Quality Evaluation

The main objective of providing services is to reduce differences between customers' expectation and what they receive to be as low as possible. To provide services much higher than customer's expectation would result in burden of service providers, while providing services lower than expectation would cause disappointment to customers and allow competitors to take away those customers.

2.2 Measurement of SLA

Performance measurement of service delivery – and therefore compliance with the SLAs – is achieved by using one or more of the following metrics: (Larson, 1998)

- Availability
- Reliability
- Serviceability
- Response
- User satisfaction.

Where the service provider exceeds the service level, the steward (client-side contract manager) may reward the provider. Conversely, where the service provider fails to achieve the agreed service level, the service provider may pay "failure credits" to the client.

1) Availability

Measurement of availability identifies the proportion (percentage) of the time that the contracted service scheduled is actually accessible and useable over a defined measurement period (e.g. weekly or monthly).

2) Reliability

Reliability defines the frequency with which the scheduled service is withdrawn or fails over a defined measurement period (e.g. not more than three failures per week).

3) Serviceability

Serviceability is an extension of reliability, and measures the duration of available time lost between the point of service failure and service reinstatement (e.g.

95 percent of network failures in any working week will be restored within 30 minutes of the failure being reported).

4) Response

Response measures the time delay between a demand for service and the subsequent reply. Response time can be measured as turnaround time, transfer time (as in the case of a help desk call) or cycle time (as for recurring system batch processing).

5) User satisfaction

User satisfaction is a measure of perceived performance relative to expectation. User satisfaction is often measured by survey using a repeatable process to track changes over time.

2.3 SLA Case Example

Researcher brings up the case of SLA that uses in the daily life and industrial business which may be seen often times, as follow;

1) Help Desk of Call Center in IT company case can be divided level of services into 3 levels. (Level three support for support service in 2001, 2001)

Level 1

This is the beginning level of receiving customer's subjects between customers and company which is general subjects. If the company cannot solve out the problem that was given by customer in this level, it will be sending to level 2.

In the level 1, there will be a differentiation between servicing each customer as it will be told in the agreement. For instance,

Table 2.1 Different level of services from the help desk

Help Desk	Hours
Gold	24 hours a day , 7 days a week
Silver	8:00 A.M.-12:00 A.M. Monday through Friday (After hours, leave a voice message for return call the following business day.)
Bronze	8:00 A.M.-4:30 P.M. Monday through Friday (After hours, leave a voice message for return call the following business day.)

Level 2

This level is a process of sending subjects to a specialist to consult the way of solving problems that happens to the customers. If the company cannot solve out the problem that was given by customer in this level, it will be sending to level 3 which is the last level.

Level 3

This level is a process of sending a specialist to see customer in person to solve the problem which occurs at that moment.

There are differences of expenses among each service level depending on customers needed. To consider which service level need to be used, it depends on the business's priority because each level has different services. As a customer, they must research their business that which service and level they need. Also, as a service provider, they need to maintain their service levels all the time in order to convince their customers to feel assured that they have received services neutrally and accurately as designated.

2) The Top courier company, FedEx Case (FedEx, 2010); the company set time guaranteed for customers when and what time exactly goods will be delivered. If the company cannot deliver goods on the date and time as they decided, the company is willing to pay deliver fees for customers. Refund must happen when company made a mistake such as the lateness of delivery system or losing goods etc.

3) For the case of timing guarantee in transferring patients in Siriraj Hospital (Faculty of Medicine Siriraj Hospital, 2004) whose work involves moving patients with cots and wheel-chairs throughout 24 hours. Currently, the hospital has to provide transferring service to patients 1,837 trips/day, on average and that caused them problems due to insufficient number of staff, resulting in delay of patient transfer. Thus they developed timing guarantee for transferring service. With the aim to develop service quality, patients were categorized into 2 groups as the followings.

Group 1 Transferring service for general patients. For outpatients, timing guarantee is set to be 15 min/trip, with the goal of 95%. For inpatients, timing guarantee is set to be 20 min/trip, with the goal of 95%.

Group 2 Transferring service for emergency patients. For outpatients, timing guarantee is set to be 5 min/trip, with the goal of 80%. For inpatients, timing guarantee is set to be 10 min/trip, with the goal of 80%.

The service time is recorded and summarized for analyses and evaluation monthly. The KPI and outcomes of this project are shown in Tables 2.2 and 2.3. Based on the data, the actual performance is above the target.

Table 2.2 Transferring service level for general patients

Type	Quantity (Case)	Target (%)	Actual (%)	Time assurance
Outpatients	480,584	95	98.01	Outpatients 20 Mins 95 %
Inpatients	44,972	95	97.55	Inpatients 25 Mins 95%
Total	525,556		97.78	

Table 2.3 Transferring service level for emergency patients

Type	Quantity (Case)	Target (%)	Actual (%)	Time assurance
Outpatients	227,968	80	89.72	Outpatients 5 Mins 80%
Inpatients	21,087	80	81.11	Inpatients 10 Mins 80%
Total	249,055		85.41	

2.4 SLA Problems

The agreement in Service Level Agreement (SLA) must be followed. SLA are usually determined by service providers. However, the agreement may sometimes have problems. Most frequent problems involve these three following aspects. (Bouman et al, 1999)

1) Unclear service specification

Details in SLA which are unclear may result in misunderstanding. This case is usually found in businesses whose services involve uptime guarantee. For example, when an internet service provider stated in its SLA that “our efficiency of internet service is 99%”, it is unclear that whether the percentage is calculated per day, per month, or per year. Therefore, service providers should make SLA as clear as possible.

2) Incomplete service specification

It is difficult to provide all services as stated in the SLA, especially in the case of unexpected events such as natural disasters, terrorist crimes, etc. The SLA may not cover such these cases of unexpected events. Therefore, customers may have to accept failure of service providers in these cases that are not covered in SLA. Otherwise they may have to file a suit against that service provider for any incurred expenses.

3) "Dead-end" SLA documents

Some contents or vocabularies used in the SLA may lead to problems between service providers and serviced customers. There may be only a few customers who can understand those vocabularies and gain benefits from the SLA, while many other customers who are not familiar with those vocabularies may become doubtful. Thus SLAs should be composed with clear explanation that allows everyone to understand the content in the same way.

2.5 Related Research on SLA Determination

For the case study of Eindhoven University of Technology, they had problem regarding management of post-sale services for computer notebooks that the university had sold to students. Bouman et al, (1999) found that the organization responsible for solving notebook problems could not provide sufficient services to all students. That made some students who did not receive timely services became disappointed and upset with the university's services. Thus the university conducted interviews with students for solutions to solve their problems. They found from the interviews that students of Computer Science, Architecture, and Chemical Engineering Departments should receive highest priority in getting services since these departments used notebooks mainly for their study. Then they used a mathematical approach to categorize levels of services into 5 levels according to importance of problems. For example, in case of Level-1 problems, which referred to notebook failure during examination period, the problem would be solved within 1 hour. For Level 5, which referred to notebook failure during regular learning period, the problem would be solved within 16 hours. This solution allowed the organization to be able to solve notebook problems of students in a timely manner. It is evident here that problems or conflicts between businesses and customers can always happen. Negotiation plays a crucial role in solving such these conflicts. Negotiation mediums are useful in assisting negotiation between businesses and customers.

Berbée. et al. (2009) had evaluated the hospital service level agreements. The objective of this research was to evaluate the development and use of SLAs in a Belgian hospital from a client’s point of view. Three important conclusions can be drawn. First, it can be concluded that the research of SLAs is easier and on first sight more advantageous during the negotiation and development phase than during the implementation phase. Second, it can be concluded that differences in effectiveness can exist between the different types of services and SLAs within one hospital or organization, implying that different services can learn from each others’ successes and failures. Last but definitely not least, it can be concluded that SLAs are certainly useful for hospitals. SLAs improve people’s insight in processes, let people think about performance measurement and, in some cases, also lead to improved services.

Bouman et al, (1999) and Berbée. et al. (2009) were interested to study service levels in the organization. Nowadays, many service providers are trying to make a promise of the quality of service to customers. This research presented analysis method to determine the service level agreement on accessibility in terms of distance which can be used as a standard of contract to customers by using gas stations in Bangkok metropolitan region as a case study.

CHAPTER III
RESEARCH METHODOLOGY

The research is designed to evaluate the Service Level Agreements (SLA) on accessibility of gas station in Bangkok metropolitan region by using Geographic Information System (GIS) as an analytical tool. The GIS analysis involves road network data for calculating the shortest between customers to the nearest gas station. With sufficient number of distance data, the statistical and probabilistic methods can be applied to determine the SLA. This chapter is divided into 3 main sections, namely Data Collection, Analytical Tools and Data Analysis

3.1 Data Collection

This section describes the data source, data contents for the study area, data manipulation, and data characteristics.

3.1.1 Data Source

The research uses Transport Fundamental Geographic Data Set (Transport FGDS) from Ministry of Transport which has already been collected. These data set were last updated on March 2007. Table 3.1 shows information on spatial data.

Table 3.1 The information of spatial data used in this study

Type	Data	Description
Polygon	Bangkok metropolitan region	The boundary of Bangkok metropolitan region
Line	Road	The Primary and Secondary road data of Bangkok metropolitan region
Point	Gas station	Location information of gas station which consists of each brand and all brands in Bangkok metropolitan region

3.1.2 Data Manipulation

Transport FGDS are recorded in Shapefile and has file type name as "Shp". There are various and a lot of information in this data set such as transportation roads data, railway data, and highway data. Transportation roads are kept in the same file and this makes it more complicate as it cannot be used as desire. Besides, it is a very big file so it is running slow. Therefore, the researcher needs to do adjustment on data using ArcGIS program to select only research boundary for the purpose of objective.

3.1.3 Data Characteristics

Spatial Data is consisted of Bangkok metropolitan region boundary, transportation routes, location of gas station and customers' location which can be described as follows;

1) Boundary data of Bangkok metropolitan region

The data type of Bangkok metropolitan region[*] is called Polygon which must consist of more than 3 points or over. The starting tariff point and ending tariff point must be at the same position so that it can be calculated area boundary and circumference. Bangkok metropolitan region consists of Bangkok, Nonthaburi, Pathumthani and Samutprakan Province. This study area has a total of 4,682 km² (Ministry of Transport, 2007). The boundary is a designated area in the research that it will be only in this boundary. This shape file is named Metro_Province.

2) Road data

Bangkok metropolitan region roads[†] are described as Line Features which can be divided into Straight lines, Angle lines and Curve lines. These lines are a combination of start points called From Node and end points called To Node which make these lines become a complete road network. The roads data are important basis data for this study as they are used for analyzing road network and determining the shortest path to travel.

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[*] Appendix A
[†] Appendix B

3) Gas station data

Gas station data* are in the form of Point features. The characteristic of the position of any point is not the size of the area and distance. In addition, data indicate coordinates x and y which can be identified the data's location, such as gas station.

Gas station detailed data are recorded in Shapefile by dividing into individual brands, one Shapefile for each in order to analyze data by each brand. So, there are 13 brands of 13 Shapefiles. The gas station data are important data that referred to the destination of consumers who travel to the nearest gas station in each brand by using Network Analyst Extension as a tool to analyze the routes. The separation of each brand into each file will make analysis process be effective.

From data collection, gas station data in Bangkok metropolitan region are last updated on March 2007. There are 1,218 gas stations and can be divided into 13 brands as shown in Table 3.2.

Table 3.2 Number of gas stations used for this study

No.	Brand	Number of stations	% of total	Density (stations/km²)
1	PTT	311	25.53	0.0664
2	BANGCHAK	205	16.83	0.0438
3	ESSO	198	16.26	0.0423
4	SHELL	193	15.85	0.0412
5	CALTEX	148	12.15	0.0316
6	PETRONAS	74	6.08	0.0158
7	SUSCO	26	2.13	0.0056
8	TPI	21	1.72	0.0045
9	MP	17	1.40	0.0036
10	PT	14	1.15	0.0030
11	MOBIL	5	0.41	0.0011
12	COSMO	4	0.33	0.0009
13	PETROASIA	2	0.16	0.0004
	Total	1,218	100.00	0.2601

In Table 3.2, compared the proportion of all brands of gas stations, the top 5 show the result with 86% are popular gas station which consists of PTT, BANGCHAK, ESSO, SHELL and CALTEX equivalent of 1,055 from 1,218 all gas

* Appendix C

stations in the study area. Reviewing the density of the number of gas stations per square kilometers (gas stations/km²), low density of gas stations is found in the study area. The density of PTT is at 0.0664 gas stations/km² and BANGCHAK is at 0.0438 gas station/km². Density of gas stations is only 0.2601 gas station/km² when calculated all brands of gas stations at the same time.

3.2 Analytical Tools

Analytical tools used for this study are Network Analyst, Hawth's Tools, Statistic Analyst and ModelBuilder which can be described as follows;

3.2.1 Network Analyst

Network Analyst is an extension to ArcGIS Desktop that helps user conduct network-based spatial analysis. With ArcGIS Network Analyst, user can create applications that build multimodal routes, provide travel directions, look for closest facilities, and create service areas and origin-destination cost matrices. (ESRI, 2010)

ArcGIS Network Analyst is a powerful extension that provides network-based spatial analysis including routing, travel directions, closest facility, and service area analysis. Using a sophisticated network data model, users can easily build networks from their geographic information system (GIS) data. ArcGIS Network Analyst enables users to dynamically model realistic network conditions, including turn restrictions, speed limits, height restrictions, and traffic conditions, at different times of the day. (ESRI, 2005)

The ability of analysis about the road network by using the equipment called Network Analyst that is able to analyze various network data, however, it depends on each research in choosing to use the equipment. The following three major features of ArcGIS are used extensively.

1) Finding the best route

Whether finding a simple route between two locations or one that visits several locations, people usually try to take the best route. But best route can mean different things in different situations.

The best route can be the quickest, shortest, or most scenic route, depending on the impedance chosen. If the impedance is time, then the best route is the quickest route. Hence, the best route can be defined as the route that has the lowest impedance, where the impedance is chosen by the user. Any valid network cost attribute can be used as the impedance when determining the best route.

2) Finding the closest facility

Finding the hospital closest to an accident, the police cars closest to a crime scene, and the store closest to a customer's address are all examples of closest facility problems. When finding closest facilities, you can specify how many to find and whether the direction of travel is toward or away from them. Once you've found the closest facilities, you can display the best route to or from them, return the travel cost for each route, and display directions to each facility. Additionally, you can specify an impedance cutoff beyond which ArcGIS Network Analyst should not search for a facility. For instance, you can set up a closest facility problem to search for hospitals within 15 minutes' drive time of the site of an accident. Any hospitals that take longer than 15 minutes to reach will not be included in the results.

3.2.2 Hawth’s Tools

Hawth’s Tools is a free extension for ArcGIS containing numerous tools that automate repetitive tasks and enable new functionality relating to ecological analyses (Beyer, 2004). The Hawth’s Tools is used to support randomization of customer’s positions function to be more efficient. It can help to randomize the customers’ location more efficiently. It can identify the area that we want to randomize.

3.2.3 Statistic Analyst

To take the distance data from the analysis by using the equipment called Network analyst to analyze with the statistic methodology, and choose to use the equipment for analyzing that are called Microsoft Excel the desired results are divided as follow;

1) The average distance ($\overline{X}$) is calculated by summation of all the distance data divided by the number of customers.

2) Median is calculated by finding a midway distance from all distance data which the distance will be sorted by ascending or descending. The midway distance will be Median then.

3) Standard Deviation (SD) measures the dispersion of all the distances to see how much the distribution of distance is there, it is used together with the average distance.

4) Coefficient of Variation (CV) is another measure of dispersive comparison between distributions of distance data in each gasoline station. It is very useful when are want to compare the dispersion of several dataset. It is computed as the ratio between SD and mean and reported in the sum of percentage.

3.2.4 ModelBuilder

Another analytical tool is ModelBuilder which works in ArcGIS program. This tool is developed to build model for working as researcher's desire in various systems. For example, it can be used to develop decision support tool for finding appropriate factory location or classify surface soil. ModelBuilder is a support tool for increasing work's efficiency, in the other words; it means to specify the process of working in model that the developer has defined. It makes the works automatically, quickly and reduces errors that might have when analyzing data. The ModelBuilder tool will be developed in ArcToolbox. The resulting file has filename type of "tbx".

3.3 Data Analysis

The research is carried out to determine the service levels agreement. A case study of gas station is chosen as an illustrative example. Figure 3.1 shows the work flow diagram which are divided into 3 sections, namely, INPUT, PROCESS and OUTPUT.

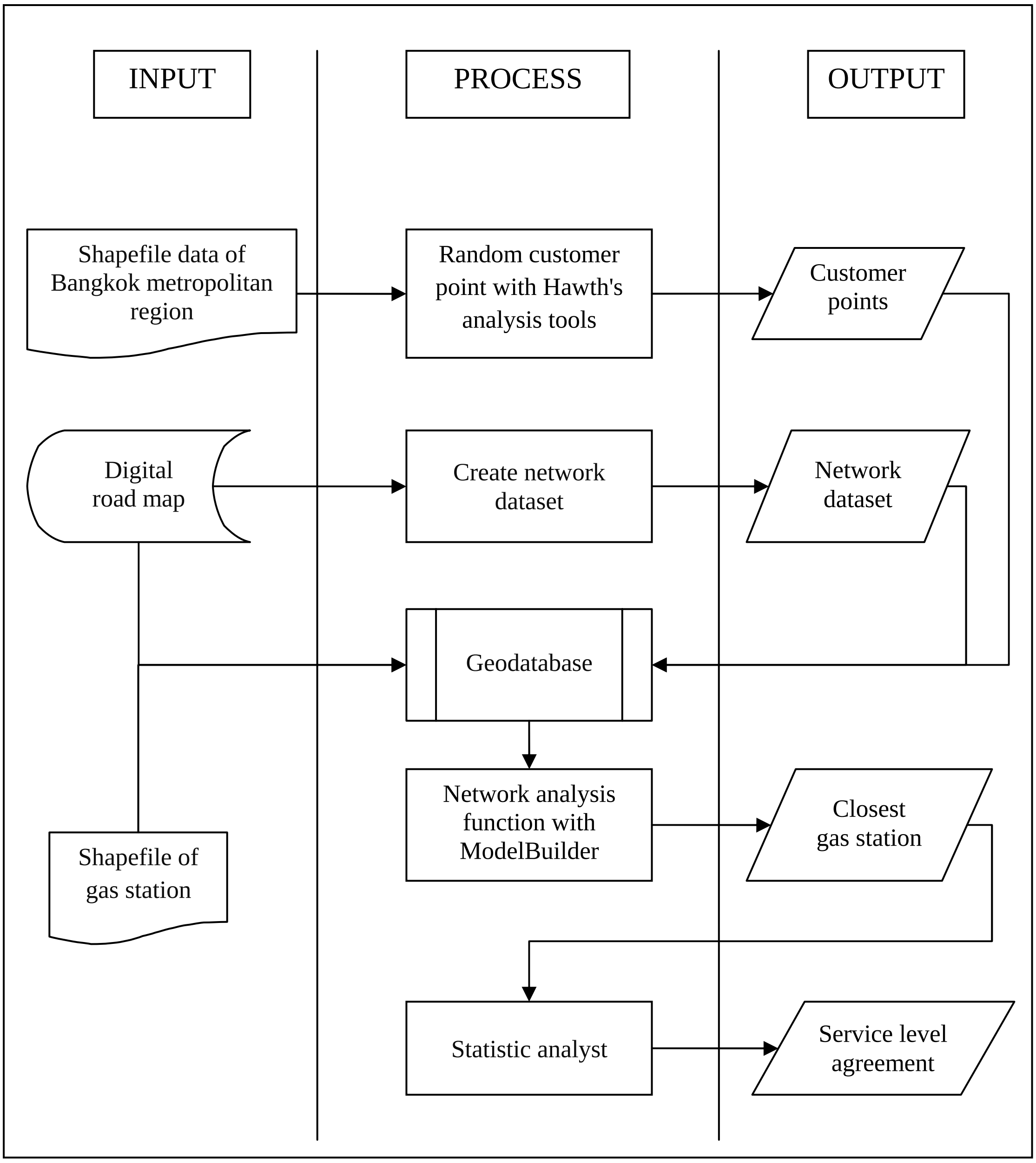

Figure 3.1 Work flow diagram

INPUT

Input data is fed into the application process of network analyst. The necessary data consists of Bangkok metropolitan region, road network data and location of gas stations. This can be described as follow;

- Shapefile data of BKK is an input of boundary of Bangkok and suburbs area which cover Bangkok, Pathumthani, Nonthaburi and Samutprakarn. These areas are using as a study area

- Digital road map is road networks data consisting of primary and secondary road networks in the study area.
- Shapefile of gas stations are data which are divided into 13 Brands consist of 1) PTT 2) BANGCHAK 3) ESSO 4) SHELL 5) CALTEX 6) PETRONAS 7) SUSCO 8) TPI 9) MP 10) PT 11) MOBIL 12) COSMO and 13) PETROASIA.

PROCESS

Procedures of Process analysis are following;

- Random customer points with Hawth's analysis tools are conducted to bring out data of BKK. It will be used to represent the set of random customer's locations in Bangkok metropolitan region.
- Create network dataset is a process of developing Network dataset* in order to use these data for analyzing by ArcGIS's Network Analyst.
- Geodatabase is a data record process which expresses in Geographic Information System database. It takes input data of Road Networks, Gas station and Customers' locations for data analysis.
- Network analysis function with ModelBuilder is a process of using Geodatabase for analyzing data to find the shortest distance from the starting point which is a random Customer's location to the closet gas Station. This analysis works by using the analytical tool developed by the ModelBuilder. The outcomes will be recorded as a set of distances.
- Statistic analyst is conducted to analyze the distance data by using principle of statistics. The results are fundamental descriptive statistics.

OUTPUT

Output from the analysis process can be described as below;

- Customer points are data from random customers which the displayed by dots in the study area. These customers' locations will be in process on Geodatabase for analysis.

* Appendix D

- Network dataset is the data from road network creation which are divided into primary and secondary roads for subsequent analysis.
- Closest gas station is resulting outcome from Network Analyst tool. This process will show distance data of customer's location travel to the closest gas station. This distance will be showed by each gas station and by all gas stations.
- Service level agreement is a distance data that can be used to refer to service levels when the analysis process is completed.

From the above research methodology, this chapter describes the process of finding service level agreement by using gas station as a case study and Geographic Information System (GIS) as an analytical test. As a result of using this method, the shortest distance can be determined accordingly.

First, the shortest distance to the nearest gas station is copied onto the Microsoft Excel for post processing. The frequency distribution is then plotted. SLA may be determined at different levels of upper bounds. When distance data and necessary statistics were received for individual gas brands. SLA on the road network can be computed to represent service for separate brands. Thereby, the competitiveness of gasoline brand may be further analyzed. In Chapter 4, the proposed methodology will be demonstrated with a case study. Results and discussions are followed.

CHAPTER IV
RESULTS AND DISCUSSIONS

This research is aimed to study about service level agreement, by choosing to study services of gas stations in Bangkok metropolitan region. Since the data of interest are relevant to transportation network, GIS has been applied in the research. In addition, statistical methodology was also employed in order to obtain distance from customers to each brand of gas stations. Details of primary study results and some discussions are as follows.

4.1 A Case Study for Petroleum Business

Petroleum in one of businesses that is related to service. This kind of business has high competition. Many companies want to own high percentage of the market share by using marketing campaign such as advertisement persuading people to use their oil. For example BANGCHAK Petroleum Public Company Limited (BCP) arranged BANGCHAK Gasohol Card which provides discount for 20 satang per liter. A customer can collect points, which is defined by 1 liter per 1 point. For every 500 points, the customer can exchange to cash 100 baht (BANGCHAK petroleum PLC, 2009). PTT Public Company Limited (PTT) has a campaign that if the customer fill gas 800 baht, he/she will receive money 3% back to account if the purchase was made via HSBC credit card (HSBC Thailand, 2009). Shell Thailand Company Limited has a campaign that if the customer fill gas 700 baht, he/she will receive money 3% back to account if the purchase is made via Citibank credit card (Citibank Thailand, 2009). All of these have affected consumer directly because they have many choices to decide which gas station they can maximize their money.

The business market share that each brand held can reflect on how successful is its operation. In Figure 4.1, it is found that PTT Public Company Limited (PTT) is No.1 in the market. The second is ESSO (Thailand) Public Company Limited

(ESSO) with market share of 12.3%, followed by Chevron (Thailand) Company Limited (CALTEX) 11.8%, Shell Thailand Company Limited (SHEEL) 11.5%, BANGCHAK Petroleum Public Company Limited (BCP) 7.6%, IRPC Public Company Limited 4.1%, Siam Gas and Petrochemicals Public Company Limited (SGP) 3.2%, World Gas (Thailand) Company Limited 2.6%, Conoco (Thailand) Company Limited 2.4% and others 9.5%. Overall, PTT Public Company Limited (PTT) has one-third in all market shares. There are just no.2 to no.5 which may be able compete to increase their market shares. Overall, they combine nearly the same market share. Under no.6 are companies that have less market share. Many factors affect gas station business including culture, social factor, economy, personal factor etc. (Prasatkeaw, 2007). Due to the advancement in technology now, it has changed consumer's behavior. New innovation is introduced for responding to their requirement. As a result, the gas station business must adapt to survive with current situation under strong competition.

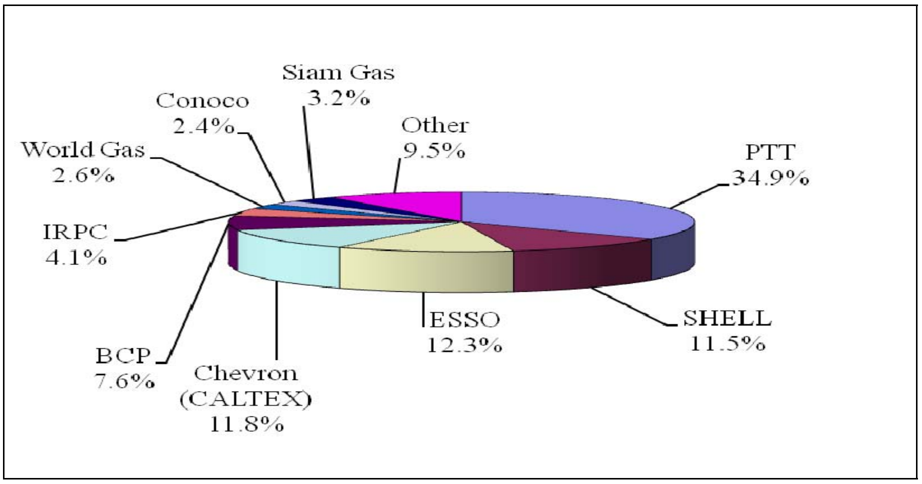

Figure 4.1 Market shares of petroleum * in 2008 (Petroleum Institute of Thailand, 2008)

Locations of service gas stations also affect accessibility of customers. Therefore, prior to setting up a gas station, the location of its site needs to be approved by the company owning the brand. Investigation is made in order to ensure that the location correspond to regulations of the company. For example, PTT Public

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* Petroleum products consist of benzene, jet fuel, kerosene, gasohol , fuel oils, and LPG

Company Limited has specified that a gas station under its brand must have a total area of at least 200 square wa. The front area along the road is at least 17.5 meters wide. The entrance must connect to a public road with a minimum width of 12 meters. Construction of the gas station can start only after approval has been given (PTT PLC, 2009).

Therefore, location of gas stations is an important factor for accessing customers. The location means the distance that customer needs to go from a point to use the service or buy a product. In addition, the ability to inform customers about the locations of gas stations under its brand, the distance to go that station, and the time needed for travelling is a useful service that a brand should provide to customers for assisting their decision making. Hence, employing information system in assessing direction, distance, and traveling time can help oil companies provide valuable information to customers.

In more detail, looking at the statistics of the number of gas station in Thailand from 2006 to 2008 in Table 4.1, it is found that the number of gas station continuously increases. By contrast, there are 18,902 gas stations in 2008 which increased from 18,534 in year 2007 or 1.98% growth. In Bangkok metropolitan region, the number of gas stations increased at the moderate rate of 1.27% during years 2007-2008. Most gas stations are concentrated in Bangkok with total number of 892 stations in 2008. The Second is Pathumthani with 215 stations. The Third is Nonthaburi with 211 stations. The last one is Samutprakan with 197 stations. The total number of gas station in Bangkok metropolitan region is 1,515 in 2008 as compared with 1,496 in 2007. The growth is 1.27% per annum as shown in Table 4.1

Table 4.1 The number of gas stations from 2006 to 2008 (Department of Energy Business, 2008)

District name	Number of gas stations			% Diff 07/08
	2006	2007	2008	
Bangkok	868	903	892	-1.22
Nonthaburi	170	200	211	5.50
Samutprakan	166	175	197	12.57
Pathumthani	209	218	215	-1.38
Bangkok metropolitan region	1,413	1,496	1,515	1.27
All over Thailand	17,993	18,534	18,902	1.98

Gas station has a role as a representative of each company which offered various types of service. The competition between companies for building up quality makes specific characteristics inside their brands in order to have an advantage over the competition. The customers' behavior has changed because they don't focus on only price but also consider other factors that have an impact on customers decision for example minimart, car washing service, toilet etc. These forms of service respond to customer's requirement (Prasatkeaw, 2007). The service quality is so important that making service different from other competitors can impress the customer.

4.2 Data Analysis

The data analysis for obtaining the closest distance from a customer to the nearest gas station was designed and developed by using ModelBuilder. The developed model comprises three stages. First of all, the model needs to know coordinates of customers to be used as beginning points. The second stage is to allow customers to choose, from prepared brands, the brand of gas stations that they prefer to go so that the nearest distance to a gas station of that brand can be analyzed. Finally, the last stage of the model is the process to calculate the distance to the nearest gas station of that selected bran. Details on model development are as follows.

4.2.1 Randomization of Customers' Coordinates

In order to analyze for closest gas stations without bias, coordinates of customers need to be randomized. Randomized coordinates of customers within the area of Bangkok metropolitan region were obtained by using Hawth's Tools. These coordinates are important, since they will be used as beginning points for determining SLA of gas stations on the road network. The analysis of closest distances from these coordinates to required brands of gas stations will derive average distance between nearest gas stations of the same brand. Results from the randomization will also yield number of customers that can access each gas station.

Hawth's Tools needs to be installed prior to being used with ArcGIS. Installation procedure of the tool is illustrated in Figure 4.2.

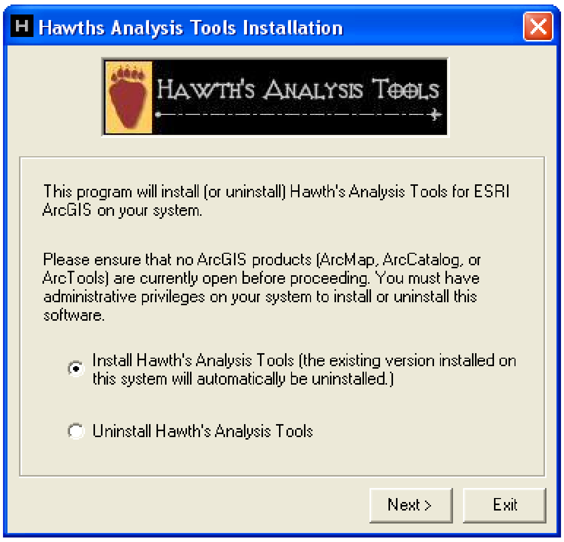

Figure 4.2 Procedures for installing the Hawth's Tools

After completion of the installation, the Hawth's Tools had not yet been available to be used. The researcher needed to select the Hawth's Tools from list of Extensions of ArcGIS before the ToolBox of Hawth's Tools will be ready to use. The researcher used Generate Random Points function of this tool to randomize coordinates of customers as shown in Figure 4.3

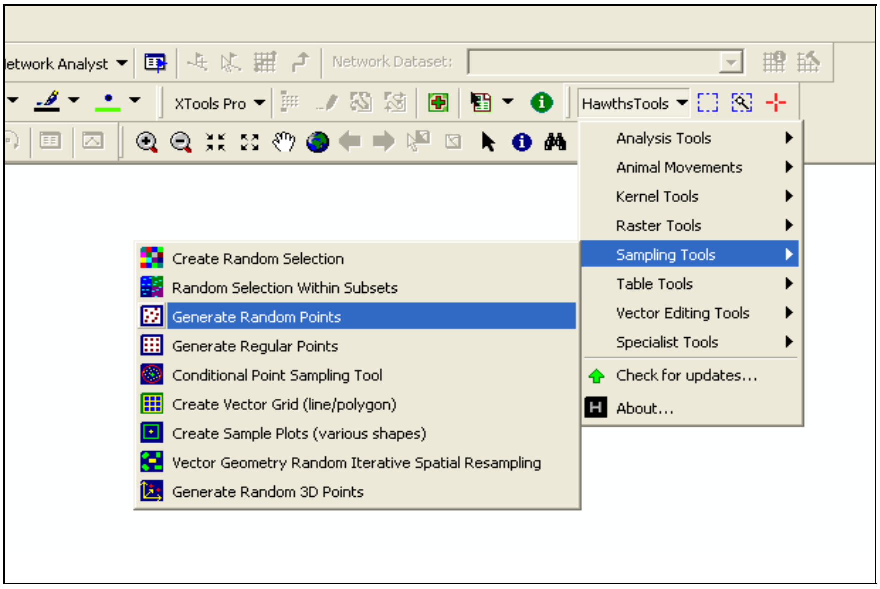

Figure 4.3 Generate Random Points function of Hawth's Tools

In order to derive point features of randomized coordinates, the randomization process requires a polygon feature to be used as boundary of those randomized points that represent locations of customers. The polygon feature used here was the boundary of Bangkok metropolitan region, which is the study area of this research. With Hawth's Tools, the researcher was able to specify any number of customers for studying. The process resulted in locations of customers that distributed randomly throughout the study area. Figure 4.4 shows the procedure of using Generate Random Points function of Hawth's Tools to generate randomized locations of customers.

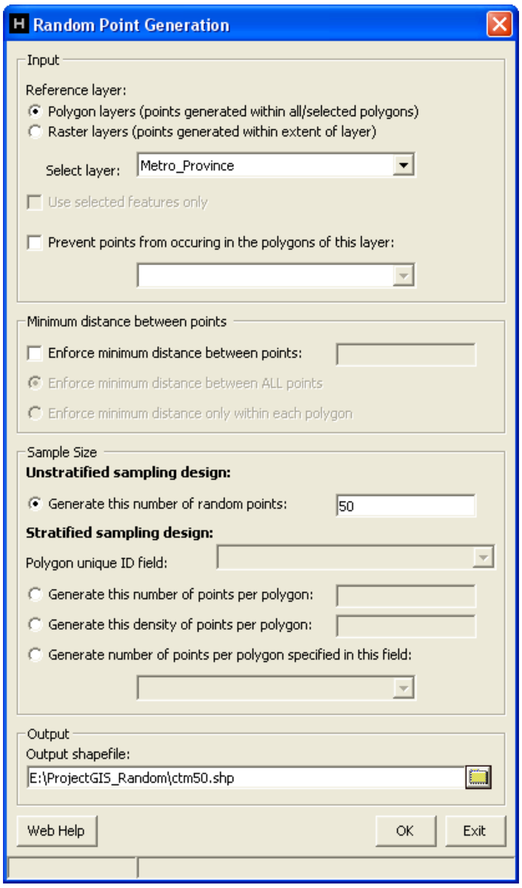

Figure 4.4 Procedure for generating randomized coordinates of customers

After completion of the randomization process, the resulting point features will appear as shown in Figure 4.5, which was the result from randomization of 50 locations of customers within the area of Bangkok metropolitan region. The output point features are in the Shapefile format.

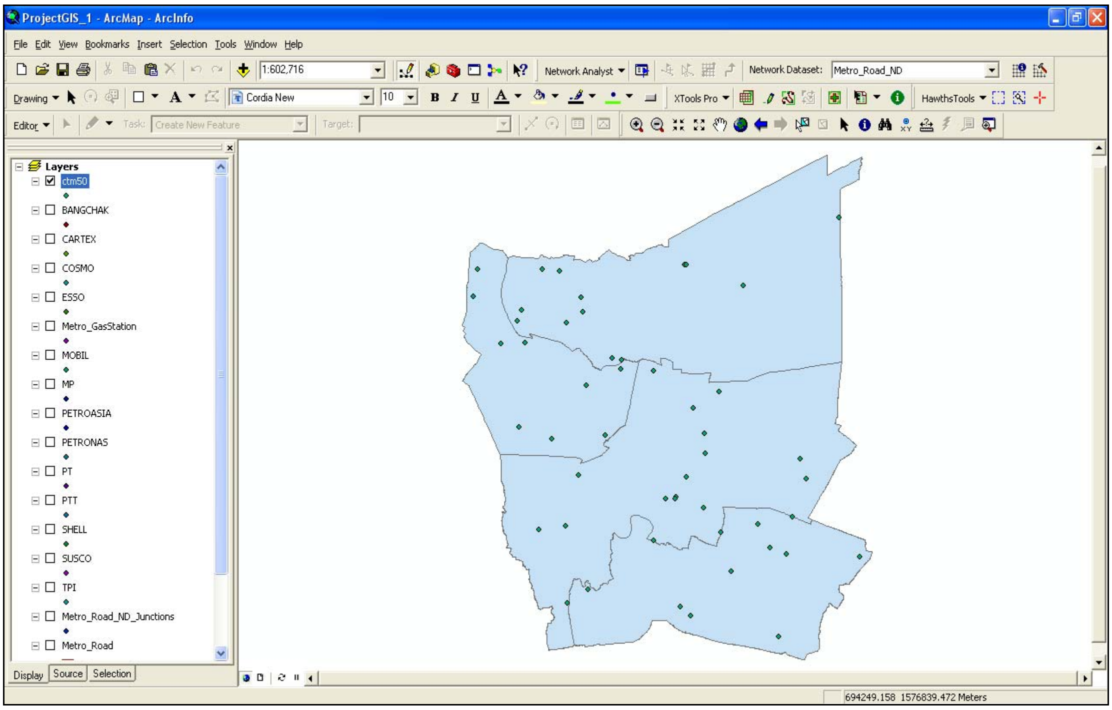

Figure 4.5 Resulting coordinates of customers from randomization process

Numbers of customers that were generated by randomization process were specified as 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000 and 10,000 respectively. It was expected that, by increasing numbers of customers gradually, the calculated distances from customers to gas stations will convert to a specific number, which represents average distance from any customer to access a gas station of the specified brand. Note that the randomization in this research is based on only one replication. Therefore, the calculated SLA is the upper-bound of the accessibility. To compute the confidence interval of SLA, more replications will be needed to derive the distribution of their mean and standard deviation.

4.2.2 Creating the Network Dataset

Prior to analyzing the road network by using Network Analyst Extension of ArcGIS, a Network Dataset is required. Analysis of appropriate route uses distance data for route analysis according to predefined properties of the Network Dataset. To analyze for the shortest distances, coordinates of customers were beginning points of the analysis, while coordinates of gas stations were ending points. Predefined properties of the Network Dataset were described below;

- Limitations of the route, such as one-way driving only. For this analysis system, routes of the roads were defined as either One-way or Two-way.
- Levels of roads, such as highway, superhighway, main road, soi (minor road), etc. For this analysis system, all roads were defined to be the same level.
- Height of roads, such as bridge, express way, etc. For this analysis system, height of roads was not defined.
- Direction of driving. This property is used to define the extent in driving direction. For this analysis system, roads' names were used as the unit of direction to be displayed.

4.2.3 Geodatabase

An ArcGIS geodatabase is a collection of geographic datasets of various types held in a common file system folder, a Microsoft Access database, or a multiuser relational database (ESRI, 2010). The geodatabase contains three primary dataset types, namely, 1 Feature classes, 2 Raster datasets, and 3 Tables.

1) Feature class is a table with a shape field containing point, line, or polygon geometries for geographic features. Each row is a feature.

2) Raster dataset contains raster which represents continuous geographic phenomena.

3) Table is a collection of rows, each containing the same fields. Feature classes are tables with shape fields.

Creating a collection of these dataset types is the first step in designing and building a geodatabase. Users typically start by building a number of these fundamental dataset types. Then they add to or extend their geodatabase with more advanced capabilities (such as by adding topologies, networks, or subtypes) to model GIS behavior, maintain data integrity, and work with an important set of spatial relationships.

Geodatabase storage includes both the schema and rule base for each geographic dataset plus simple, tabular storage of the spatial and attribute data. All three primary datasets in the geodatabase (feature classes, attribute tables, and raster datasets) as well as other geodatabase elements are stored using tables. The spatial representations in geographic datasets are stored as either vector features or as rasters. These geometries are stored and managed in attribute columns along with traditional tabular attribute fields

A feature class is stored as a table. Each row represents one feature. In the polygon feature class table (shown in Table 4.2), the Shape column holds the polygon geometry for each feature. The value Polygon is used to specify that the field contains the coordinates and geometry that defines one polygon in each row

Table 4.2 Geodatabase storage in tables and files

OBJECTID	SHAPE*	AREA	PERIMETER	NEWC_LU84_UTM_
1941	Polygon	1417540.1	11841.867	2
1942	Polygon	321332.03	3148.0269	3
1943	Polygon	18495728	109063.23	4
1944	Polygon	274196.16	3101.4026	5
1945	Polygon	381471.69	3409.4033	6
1946	Polygon	136670.41	1542.3058	7
1947	Polygon	86315.867	1170.6542	8
1948	Polygon	58569.234	1058.4961	9
1949	Polygon	126296.43	1630.2814	10
1950	Polygon	2177367.8	11357.415	11
1951	Polygon	126567.98	1486.1949	12
1952	Polygon	131079.53	1655.1431	13
1953	Polygon	29051224	116835.71	14
1954	Polygon	851969.69	4640.5933	15
1955	Polygon	189941.86	1732.4786	16
1956	Polygon	195032.53	1994.8439	17
1957	Polygon	50374.406	896.4881	18

4.2.4 Procedures for Working on ModelBuilder

This research used ModelBuilder as a tool for developing the analysis system that was used to search for the nearest gas stations. The diagram in Figure 4.6 illustrates procedures for finding the nearest gas station to a random customer. These procedures can be explained according to order of objects in the model as follows.

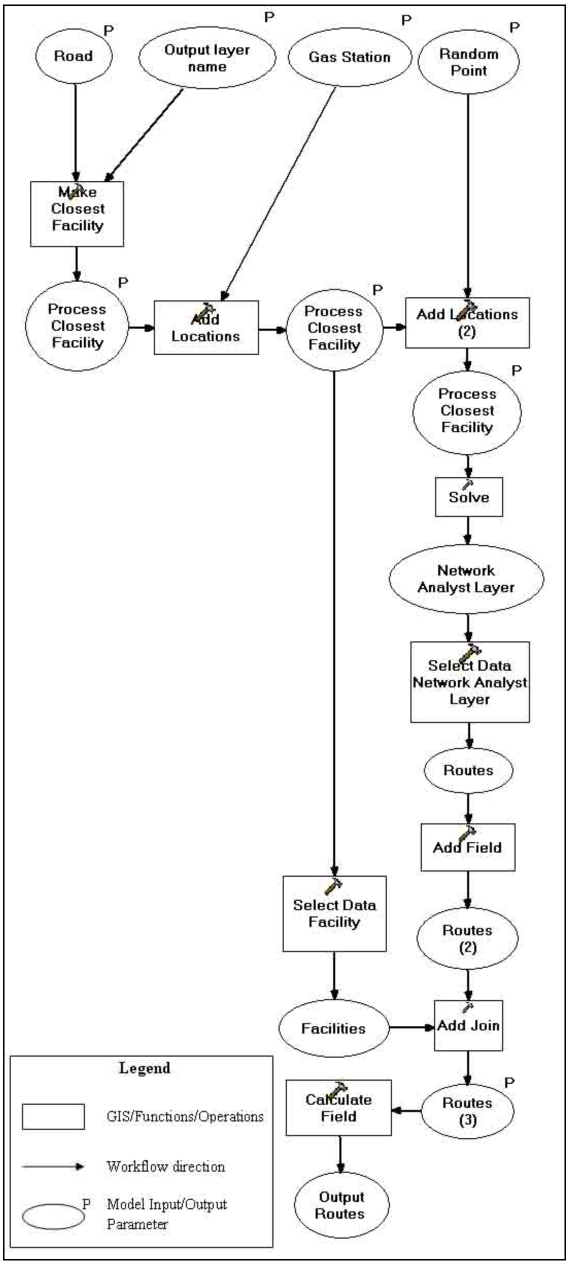

Figure 4.6 Procedures of the analysis system in searching for the nearest gas stations

1) Road

This object is from the prepared Network Dataset. It is used for route analysis. This research used road data within the area of Bangkok metropolitan region.

2) Output layer name

This object is for the filename of the output data.

3) Gas station

This object is for choosing the brand of gas stations to be searched by user

4) Random Point

This object is for the filename of point features that represent customers' locations.

The next step is to calculate the shortest travel distance between a random customer to the nearest gas station. It begins by using coordinates of customers as starting points and the nearest gas stations on the road network as ending points or destinations. The process will yield information of the nearest gas station and the distance. Details of these procedures are explained below.

5) Make Closest Facility

This is the tool for creating nearest facility. There are two steps for this procedure, namely:

- Facility. This tool is for defining locations of facility of interest. For this research, this object is set to be locations of gas stations.
- Incident. This tool is for defining locations of incident places. In this case, this object is set to be locations of randomized consumers.

6) Add Locations

This tool is for importing data. The imported data in this case is data on the location of gas stations, which has been saved in the Facility procedure.

7) Add Locations (2)

This tool is for importing data similarly to the previous procedure. However, the imported data here is the locations of consumers, which has been saved in the Incident procedure.

8) Solve

This procedure is for finding the nearest gas station by using Dijkstra's Algorithm.

9) Select Data

This procedure is for selecting the route that has been processed so that the route can be displayed. This route refers to the route from customers to the nearest gas station.

10) Add Field

This tool is for adding the Kilometers field in attribute table of route data in order to contain distance information, which is shown in kilometer.

11) Add Join

This tool is for joining attribute table of Facility with attribute table of Route.

12) Calculate Field

This tool is for calculating a field with required operation. For this model, we use this tool for converting distance unit from meter into kilometer. This requires the field to be divided by 1,000. The field that this tool was implemented was CFRoutes.Total_Meters. Thus the formula for calculating the field of shortest distance to the nearest gas station in kilometers is [CFRoutes.Total_Meters]/1000.

After completion of developing the research tools by using ModelBuilder, they are ready for the analysis. Figure 4.7 presents the windows of the developed toolbox for analyzing distance to the nearest gas station. Objects in this toolbox included:

1) Random customer points is for importing data of customers' locations.

2) Gas stations is for specifying the brand of gas stations to be searched for.

3) Road network for choosing road network that has been defined. This research used main roads and secondary roads in Bangkok metropolitan region.

4) Output layer name is for specifying the name of the output layer.

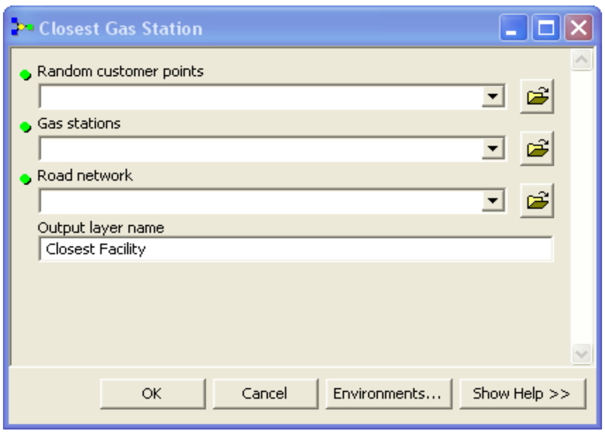

Figure 4.7 Interface of the developed tools to find the nearest gas station

4.3 Procedures for Assessing Levels of Service

In order to assess the average shortest distance to gas stations, the researcher tested by determining various numbers of randomized locations of customers; starting from 50 customers and increasing gradually to 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000 and 10,000 respectively. Coordinate information of customers were used as the beginning points for finding shortest distance to the nearest gas stations of a specified brand. Tools for this analysis are shown in Figure 4.8. There were two methodologies for the test: the first methodology is finding average distances to the nearest gas stations of each brand; and the second methodology is finding the average distance to the nearest gas station of any brand. Details of these methodologies are explained below.

4.3.1 Finding the Average Distances to the Nearest Gas Stations of Each Brand

The analysis for finding distances to gas stations of each brand is aimed to measure accessibility of customers to the nearest gas stations of each brand by using distance from a random customer to gas station as the measure. With this approach, each customer is assumed to choose the nearest gas stations for all 13 brands. The search will start by finding distance from the customer to the nearest BANGCHAK gas station. The distance will be recorded. Then the procedures will be repeated for all remaining brands until all the 13 brands have been searched. This approach gives information about distances to gas stations of each brand.

Results from finding nearest gas stations are shown in Table 4.3. Results are different depending on numbers of customers and brands of gas stations. This figure shows the result of finding distances from coordinates of 50 customers to their nearest respective BANGCHAK gas stations.

Table 4.3 Distances from 50 randomized customers to their respective the nearest BANGCHAK gas stations

Attributes of Routes

IncidentID	Total_Meters	Kilometers	ObjectID	Name
1	397.340581	.3973	7	สถานีบริการน้ำมันบางจาก
2	3595.883636	3.5959	45	สถานีบริการน้ำมันบางจาก
3	6718.049881	6.718	174	สถานีบริการน้ำมันบางจาก
4	4892.898744	4.8929	86	สถานีบริการน้ำมันบางจาก
5	12634.891324	12.6349	94	สถานีบริการน้ำมันบางจาก
6	10808.974014	10.809	29	สถานีบริการน้ำมันบางจาก
7	2459.137874	2.4591	73	สถานีบริการน้ำมันบางจาก
8	2320.778813	2.3208	177	สถานีบริการน้ำมันบางจาก
9	6352.893432	6.3529	157	สถานีบริการน้ำมันบางจาก
10	4187.012902	4.187	51	สถานีบริการน้ำมันบางจาก
11	6765.616436	6.7656	65	สถานีบริการน้ำมันบางจาก
12	5178.744713	5.1787	86	สถานีบริการน้ำมันบางจาก
13	1274.128198	1.2741	67	สถานีบริการน้ำมันบางจาก

Record: 1 Show: All Selected Records (0 out of 49 Selected) Options

As shown in Table 4.3, the results comprise several field names. IncidentID is the field of customers' locations. Total_meters is the field of distances in meter. Kilometers is the field of distances in kilometers. ObjectID is the field of gas stations' codes. Lastly, Name is the field of gas stations' brand names. For example, row 2 of the table contains information of customer number 2 who can access the nearest BANGCHAK gas station at a distance of 3,595.88 meters, or about 3.60 kilometers.

Results from the experiment to find the nearest gas stations for all 13 brands with increasing numbers of randomized customers (50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000 and 10,000) are shown in Table 4.4.

Table 4.4 Summary of results on the average shortest distance for each brand

Brand	Number of Stations	Number of random customers: 50	100	200	300	400	500
PTT	311	5.70 (3.65) (64.06)	5.38 (3.77) (70.04)	6.12 (4.65) (75.98)	6.24 (4.54) (72.79)	6.03 (4.38) (72.70)	5.97 (4.55) (76.13)
BANGCHAK	205	5.48 (3.40) (62.14)	5.39 (3.66) (67.83)	6.17 (3.78) (61.14)	6.12 (4.23) (69.14)	6.32 (4.20) (66.41)	5.77 (4.23) (73.41)
ESSO	198	6.06 (5.02) (82.81)	6.91 (4.72) (68.27)	7.85 (5.39) (68.63)	7.52 (5.11) (67.96)	7.87 (5.68) (72.15)	7.29 (5.45) (74.73)
SHELL	193	7.31 (5.02) (68.69)	7.57 (4.72) (62.32)	9.11 (5.39) (59.18)	8.64 (5.11) (59.11)	9.21 (5.68) (61.63)	8.31 (5.45) (65.58)
CALTEX	148	7.80 (6.97) (89.36)	9.17 (7.48) (81.52)	11.26 (9.53) (84.65)	10.25 (8.52) (83.12)	10.99 (9.17) (83.42)	10.38 (8.73) (84.11)
PETRONAS	74	11.51 (9.29) (80.66)	13.66 (11.59) (84.88)	16.31 (13.83) (84.82)	14.34 (12.02) (83.86)	15.93 (13.47) (84.57)	14.78 (12.49) (84.50)
SUSCO	26	14.05 (9.21) (65.54)	14.06 (9.20) (65.45)	16.04 (11.36) (70.82)	14.65 (10.21) (69.73)	16.31 (11.28) (69.16)	14.81 (10.27) (69.35)
TPI	21	11.06 (6.97) (63.06)	14.20 (9.18) (64.69)	16.58 (11.23) (67.76)	14.62 (10.04) (68.64)	16.30 (10.70) (65.63)	15.44 (10.17) (65.86)
MP	17	12.60 (7.11) (56.45)	14.11 (7.40) (52.48)	16.41 (8.63) (52.59)	14.41 (7.96) (55.26)	15.72 (8.44) (53.72)	14.94 (8.13) (54.44)
PT	14	14.21 (8.37) (58.88)	17.61 (11.26) (63.93)	19.48 (12.82) (65.84)	18.37 (11.83) (64.39)	19.48 (12.64) (64.90)	18.87 (11.99) (63.53)
MOBIL	5	20.70 (12.22) (59.04)	24.45 (12.53) (51.26)	27.06 (14.05) (51.92)	25.37 (12.97) (51.12)	27.10 (13.77) (50.83)	25.57 (12.87) (50.32)
COSMO	4	24.63 (10.16) (41.25)	22.38 (9.92) (44.31)	23.49 (10.34) (44.01)	22.80 (10.91) (47.86)	23.94 (11.24) (46.95)	22.74 (10.75) (47.27)
PETROASIA	2	31.78 (13.42) (42.24)	31.45 (12.93) (41.13)	31.80 (14.53) (45.70)	32.42 (14.63) (45.11)	32.37 (13.66) (42.21)	32.20 (13.85) (43.00)

Notation: Numbers in parentheses are the Standard Deviation (SD) and Coefficient of Variation (CV)

Table 4.4 Summary of results on the average shortest distance for each brand (cont.)

Brand	Number of random customers						
	600	**700**	**800**	**900**	**1000**	**2000**	**3000**
PTT	6.06	6.00	6.23	6.22	6.42	6.22	6.12
	(4.34) (71.53)	(4.20) (70.08)	(4.53) (72.68)	(4.59) (73.84)	(4.44) (69.22)	(4.59) (73.77)	(4.49) (73.38)
BANGCHAK	5.86	5.88	6.13	6.20	6.39	6.24	6.12
	(3.89) (66.28)	(3.88) (66.07)	(4.18) (68.11)	(4.34) (70.09)	(4.06) (63.63)	(4.32) (69.21)	(4.22) (68.94)
ESSO	7.26	7.20	7.48	7.68	7.77	7.40	7.52
	(4.94) (68.06)	(4.84) (67.20)	(5.22) (69.76)	(5.52) (71.92)	(5.29) (68.10)	(5.43) (73.40)	(5.41) (71.94)
SHELL	8.51	8.50	8.78	8.96	9.12	8.84	8.74
	(4.94) (58.04)	(4.84) (56.93)	(5.22) (59.48)	(5.52) (61.61)	(5.29) (58.00)	(5.43) (61.46)	(5.41) (61.92)
CALTEX	10.30	10.11	10.44	10.69	11.02	10.68	10.37
	(8.43) (81.89)	(8.24) (81.50)	(8.49) (81.33)	(9.26) (86.61)	(8.81) (79.92)	(9.01) (84.35)	(8.72) (84.08)
PETRONAS	15.25	14.04	14.94	15.60	15.56	15.20	14.92
	(12.30) (80.63)	(11.58) (82.52)	(12.24) (81.90)	(13.21) (84.71)	(12.61) (81.08)	(12.71) (83.59)	(12.44) (83.36)
SUSCO	15.16	14.32	15.22	16.07	15.95	15.38	15.44
	(10.04) (66.23)	(9.71) (67.79)	(10.31) (67.75)	(11.04) (68.69)	(10.66) (66.87)	(10.60) (68.93)	(10.47) (67.83)
TPI	15.36	14.88	15.63	15.77	15.78	15.78	15.35
	(9.86) (64.19)	(9.69) (65.13)	(10.01) (64.02)	(10.62) (67.32)	(10.22) (64.80)	(10.39) (65.86)	(10.18) (66.32)
MP	15.14	14.67	15.29	15.46	15.48	15.56	15.30
	(8.09) (53.40)	(7.66) (52.24)	(8.05) (52.64)	(8.72) (56.42)	(8.09) (52.30)	(8.17) (52.49)	(8.20) (53.57)
PT	18.88	18.72	18.79	19.13	19.09	19.01	18.67
	(11.83) (62.68)	(11.85) (63.30)	(12.14) (64.57)	(12.22) (63.88)	(11.87) (62.20)	(12.33) (64.89)	(12.04) (64.51)
MOBIL	25.99	25.18	25.96	26.18	26.83	26.01	25.93
	(12.88) (49.56)	(12.41) (49.26)	(13.34) (51.37)	(14.05) (53.67)	(13.16) (49.04)	(13.50) (51.91)	(13.28) (51.22)
COSMO	23.55	22.91	23.83	24.24	24.22	23.43	23.81
	(10.75) (45.64)	(9.96) (43.50)	(10.87) (45.61)	(11.36) (46.87)	(11.22) (46.31)	(10.90) (46.55)	(11.03) (46.33)
PETROASIA	31.55	32.44	32.11	31.51	32.41	32.20	31.74
	(13.18) (41.77)	(13.45) (41.46)	(14.11) (43.93)	(13.85) (43.97)	(13.72) (42.35)	(13.90) (43.16)	(13.88) (43.73)

Notation: Numbers in parentheses are the Standard Deviation (SD) and Coefficient of Variation (CV)

Table 4.4 Summary of results on the average shortest distance for each brand (cont.)

Brand	Number of random customers													
	4000		5000		6000		7000		8000		9000		10000	
PTT	6.19		6.15		6.17		6.01		6.14		6.12		6.08	
	(4.51)	(72.88)	(4.50)	(73.22)	(4.46)	(72.34)	(4.44)	(73.81)	(4.52)	(73.63)	(4.41)	(72.07)	(4.46)	(73.25)
BANGCHAK	6.23		6.12		6.18		6.02		6.09		6.13		6.14	
	(4.26)	(68.34)	(4.22)	(68.97)	(4.15)	(67.24)	(4.12)	(68.50)	(4.14)	(67.92)	(4.18)	(68.15)	(4.19)	(68.22)
ESSO	7.53		7.50		7.47		7.37		7.42		7.55		7.42	
	(5.46)	(72.42)	(5.27)	(70.25)	(5.31)	(71.05)	(5.25)	(71.23)	(5.27)	(71.03)	(5.36)	(71.06)	(5.30)	(71.50)
SHELL	8.74		8.67		8.74		8.59		8.68		8.73		8.62	
	(5.46)	(62.42)	(5.27)	(60.77)	(6.23)	(71.28)	(6.17)	(71.76)	(6.18)	(71.26)	(6.24)	(71.41)	(6.15)	(71.26)
CALTEX	10.40		10.35		10.51		10.30		10.40		10.44		10.37	
	(8.74)	(84.06)	(8.58)	(82.95)	(8.80)	(83.73)	(8.69)	(84.38)	(8.69)	(83.60)	(8.63)	(82.61)	(8.61)	(83.07)
PETRONAS	14.89		14.92		15.15		14.83		14.93		15.12		14.79	
	(12.33)	(82.77)	(12.22)	(81.89)	(12.57)	(82.98)	(12.40)	(83.62)	(12.35)	(82.70)	(12.36)	(81.76)	(12.23)	(82.68)
SUSCO	15.17		15.28		15.34		15.01		15.19		15.31		15.14	
	(10.62)	(69.98)	(10.33)	(67.65)	(10.50)	(68.47)	(10.36)	(68.98)	(10.38)	(68.38)	(10.43)	(68.12)	(10.40)	(68.70)
TPI	15.31		15.21		15.45		15.22		15.39		15.44		15.25	
	(10.09)	(65.93)	(10.01)	(65.79)	(10.28)	(66.54)	(10.13)	(66.53)	(10.11)	(65.71)	(10.05)	(65.10)	(9.97)	(65.38)
MP	15.30		15.15		15.30		15.08		15.29		15.42		15.14	
	(8.10)	(52.96)	(7.98)	(52.64)	(8.23)	(53.78)	(8.12)	(53.84)	(8.11)	(53.05)	(8.01)	(51.91)	(8.03)	(53.02)
PT	18.46		18.65		18.87		18.71		18.77		18.83		18.54	
	(11.93)	(64.61)	(11.87)	(63.63)	(12.01)	(63.67)	(11.87)	(63.43)	(11.98)	(63.83)	(11.85)	(62.91)	(11.87)	(64.03)
MOBIL	25.78		25.93		25.88		25.61		25.80		26.00		25.79	
	(13.29)	(51.56)	(13.08)	(50.43)	(13.26)	(51.23)	(13.13)	(51.25)	(13.17)	(51.06)	(13.06)	(50.23)	(13.20)	(51.18)
COSMO	23.87		23.78		23.61		23.31		23.66		23.68		23.71	
	(11.10)	(46.49)	(10.95)	(46.03)	(10.82)	(45.84)	(10.78)	(46.24)	(10.78)	(45.57)	(10.90)	(46.05)	(11.05)	(46.62)
PETROASIA	31.92		31.77		31.93		31.70		31.86		31.62		31.96	
	(13.83)	(43.34)	(14.03)	(44.17)	(13.93)	(43.64)	(13.83)	(43.63)	(13.99)	(43.90)	(13.96)	(44.14)	(13.99)	(43.77)

Notation: Numbers in parentheses are the Standard Deviation (SD) and Coefficient of Variation (CV)

Results in Table 4.4, can be explained by using PTT and Shell gas stations as the two illustrative examples:

1) PTT gas stations

During the early stage of the experiment, with numbers of customers increasing gradually from 50 to 1,000 customers, the average distances from customers to the nearest PTT gas stations ranged between 5.7 - 6.42 kilometers, while standard deviations ranged between 3.65 - 4.44 kilometers. The trend of these averages and standard deviations appears to be varying in this early stage, which implies fluctuation of distances from customers to PTT gas stations. However, in later stage, with number of customers increasing from 2,000 to 10,000 customers, the distances seem to be steady, with little fluctuation.

2) SHELL gas stations

During the early stage of the experiment, with numbers of customers increasing gradually from 50 to 1,000 customers, the average distances from customers to the nearest Shell gas stations ranged between 7.31 - 9.12 kilometers, while standard deviations of the distances ranged between 5.02 - 5.29 kilometers. It can be seen that the trend of these averages and standard deviations appears to be varying in this early stage, which implies fluctuation of distances from customers to Shell gas stations. However, in later stage, with number of customers increasing from 2,000 to 10,000 customers, the distances seem to be steady, with little fluctuation.

The researcher made the comparative analysis of accessible distance to PTT and Shell gas stations. The main reason for PTT to have less average shortest distance than Shell stations is because of its larger numbers of 311 gas stations as compared to 193 of Shell gas stations. The difference of 118 stations does matter in terms of the reduction in the average nearest distance from 8.62 kilometers in the case of Shell down to 6.08 kilometers in the case of PTT at the 10,000 randomized customers. The variation in the mean, measured by the CV, is rather similar. PTT shows CV at 73.25% whereas it is 71.26% for Shell.

The resulting average distances for individual gasoline brands in Table 4.4 were plotted on graphs in Figures 4.8 to 4.20, to observe the convergence of the simulation. The X-axis represents the number of randomized customers. The Y-axis represents the number of average nearest distances. It can be seen clearly that the number of randomized customers affects the results.

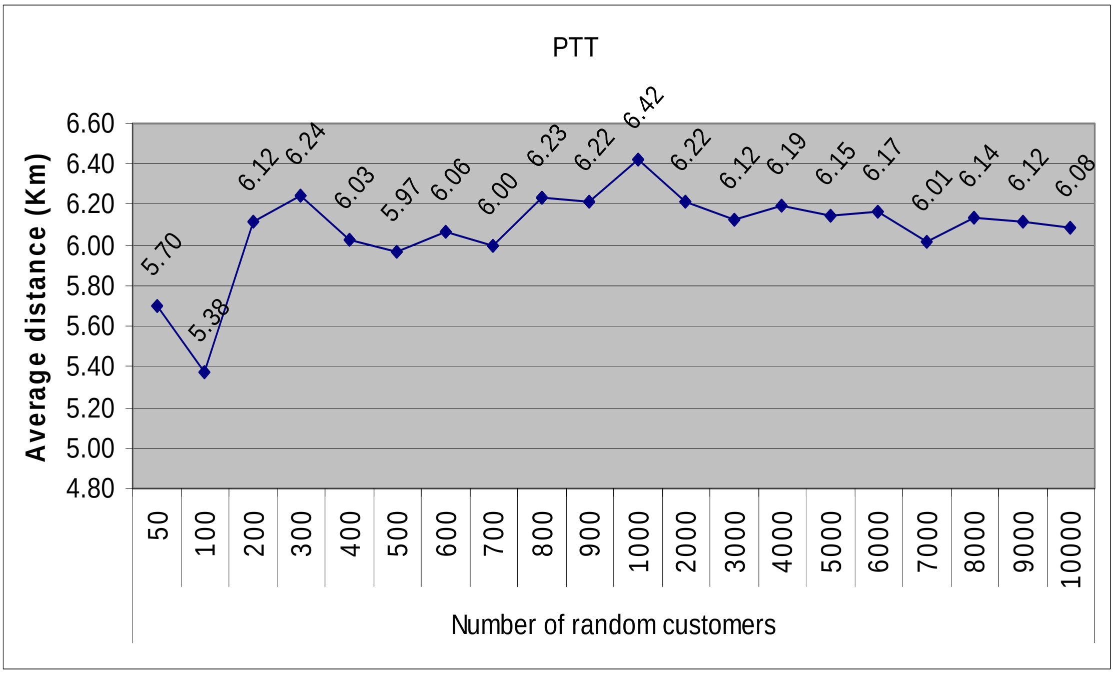

Figure 4.8 Average distance from a random customer to the nearest PTT gas stations

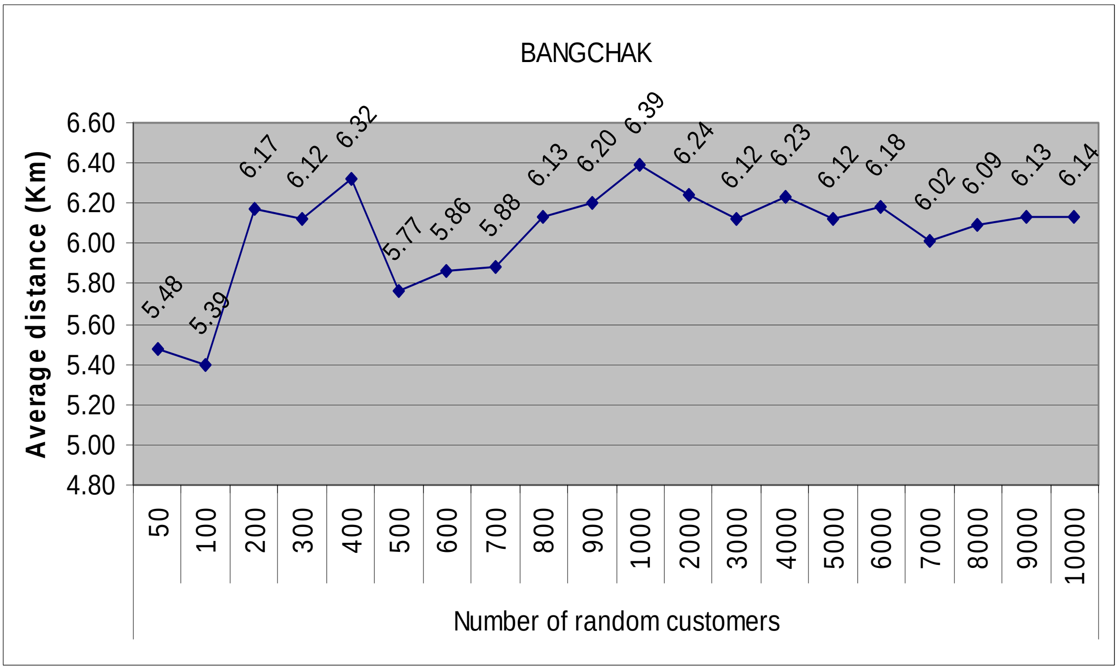

Figure 4.9 Average distance from a random customer to the nearest BANGCHAK gas stations

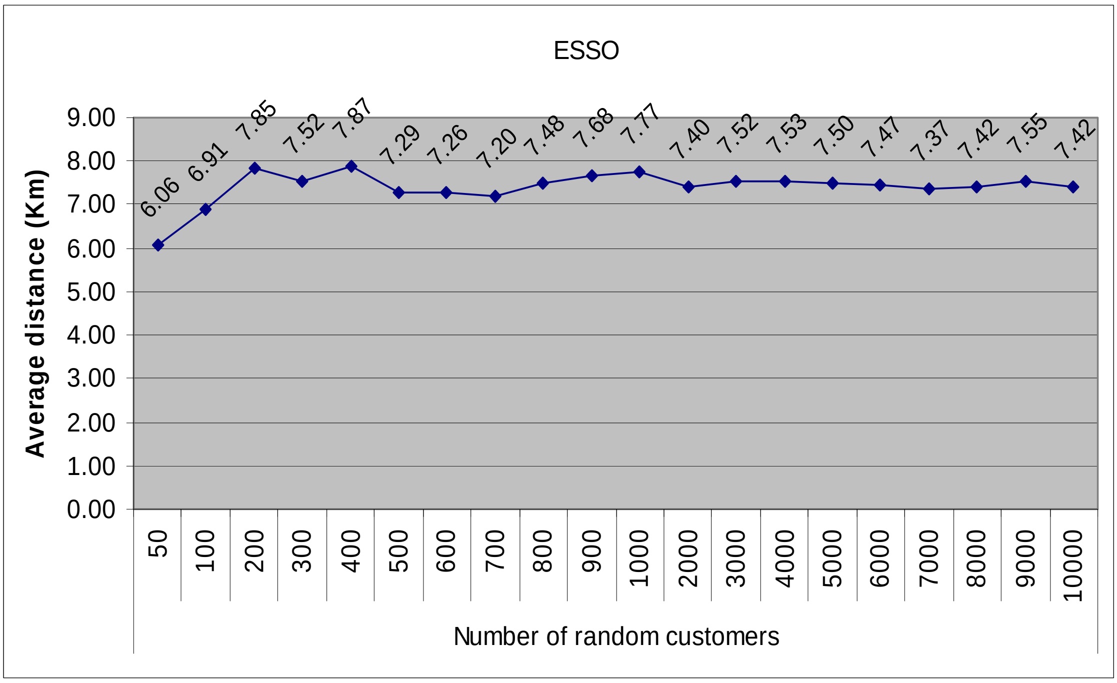

Figure 4.10 Average distance from a random customer to the nearest ESSO gas stations

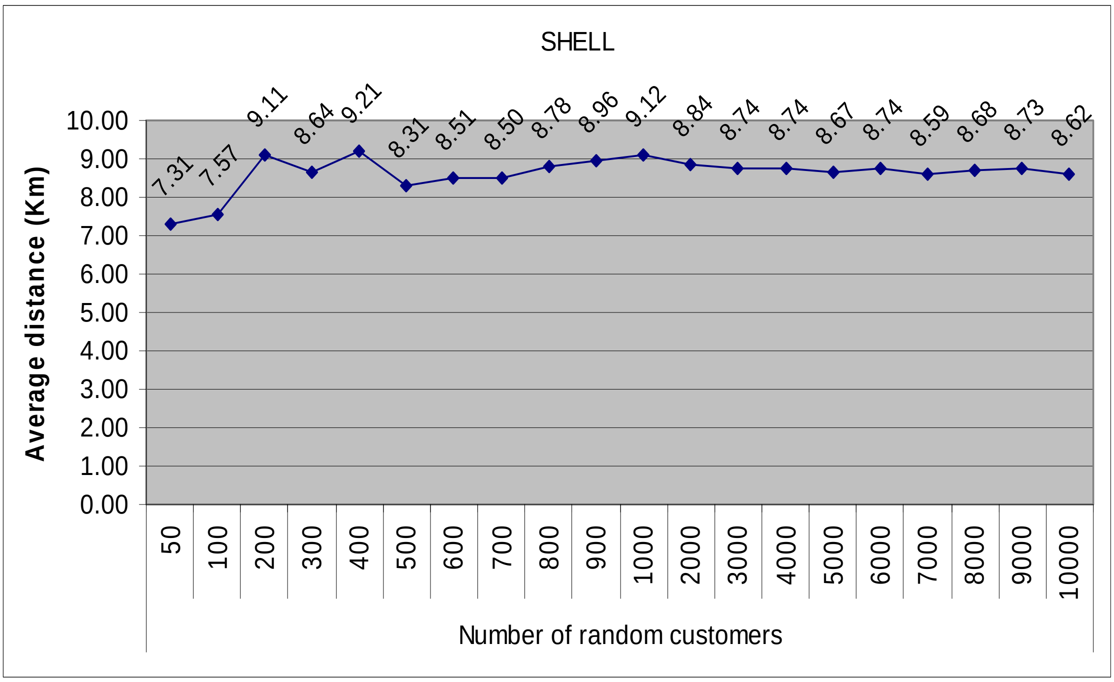

Figure 4.11 Average distance from a random customer to the nearest SHELL gas stations

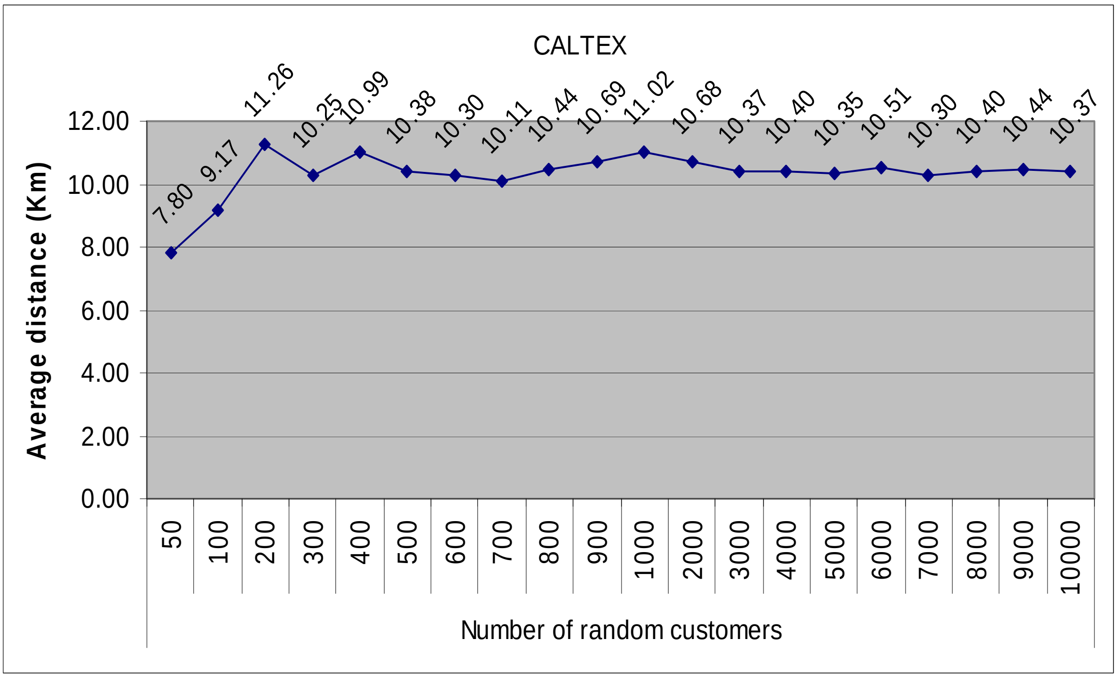

Figure 4.12 Average distance from a random customer to the nearest CALTEX gas stations

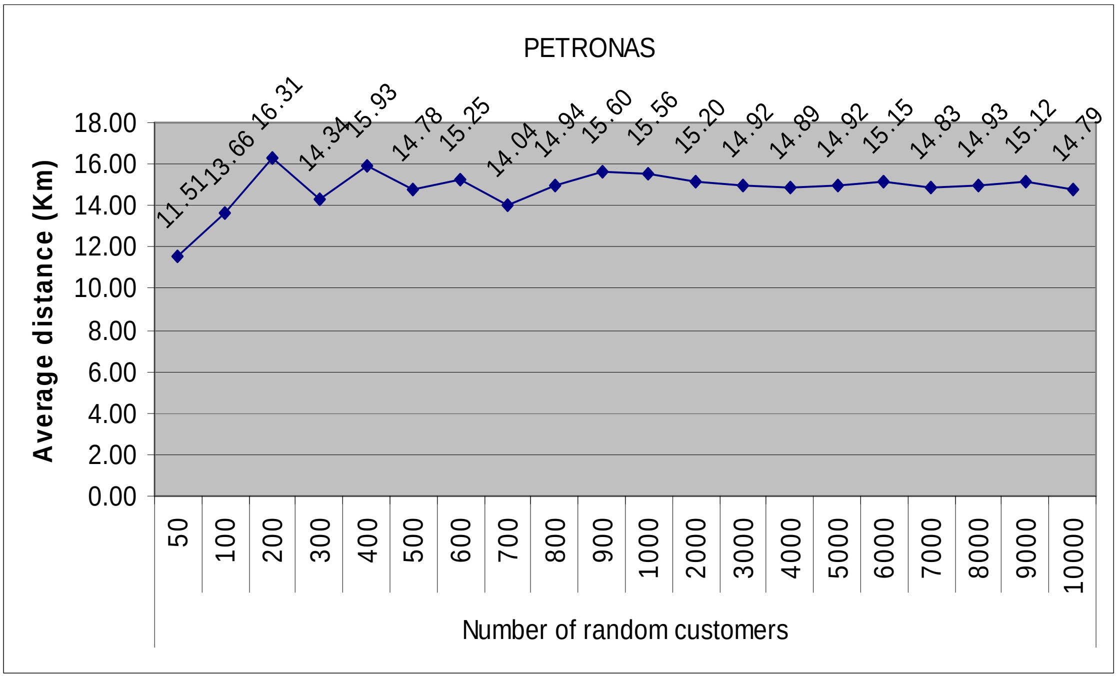

Figure 4.13 Average distance from a random customer to the nearest PETRONAS gas station

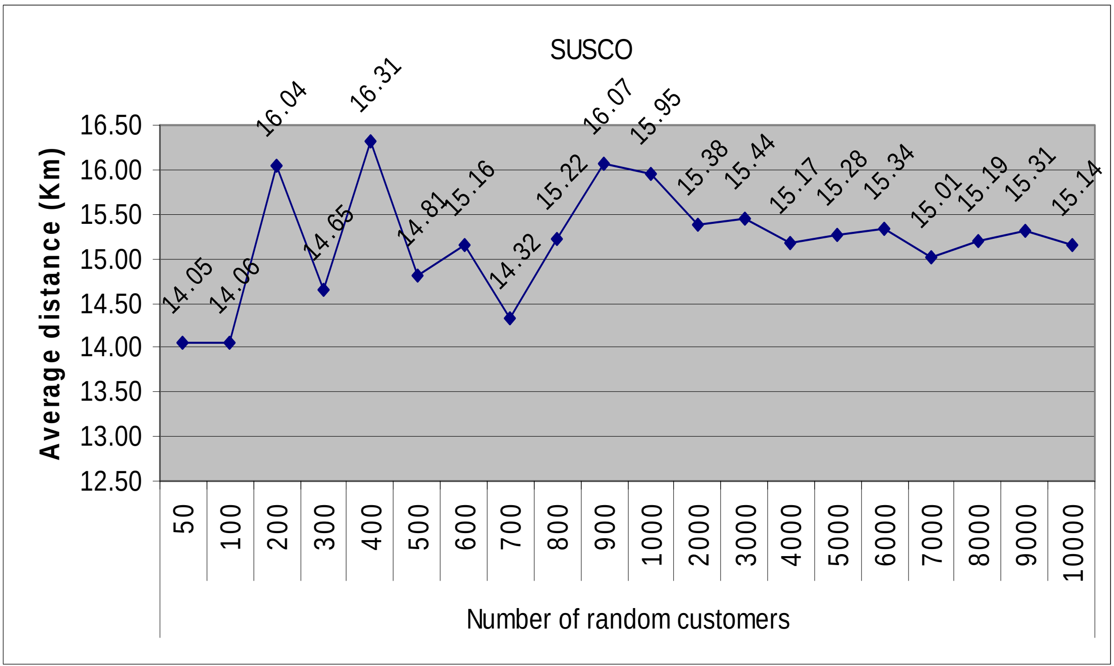

Figure 4.14 Average distance from a random customer to the nearest SUSCO gas stations

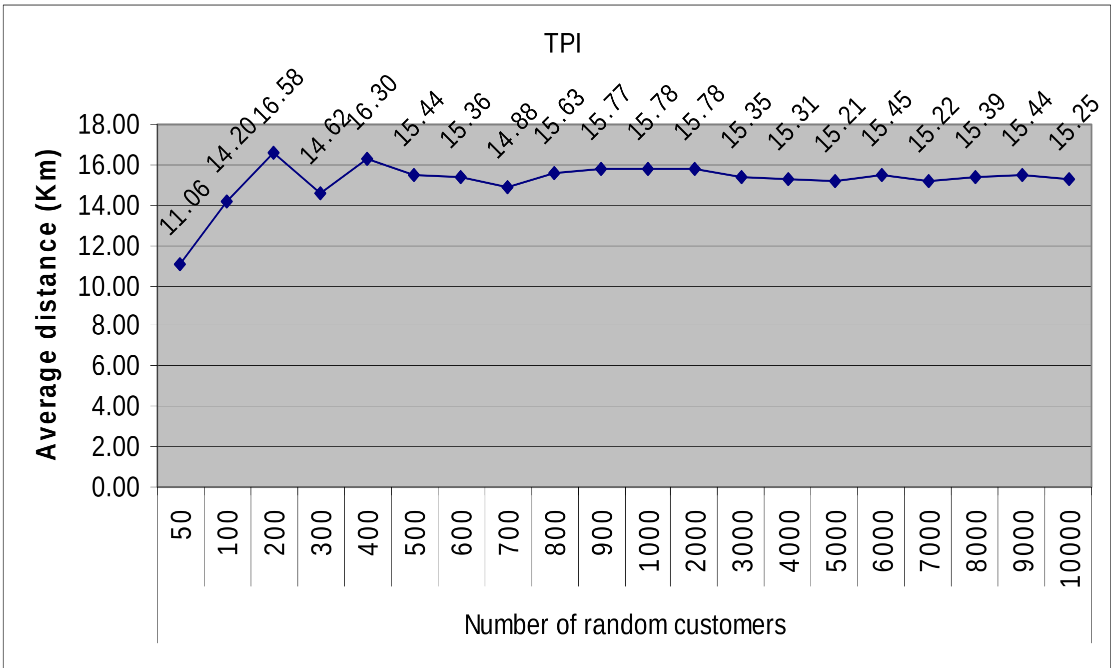

Figure 4.15 Average distance from a random customer to the nearest TPI gas stations

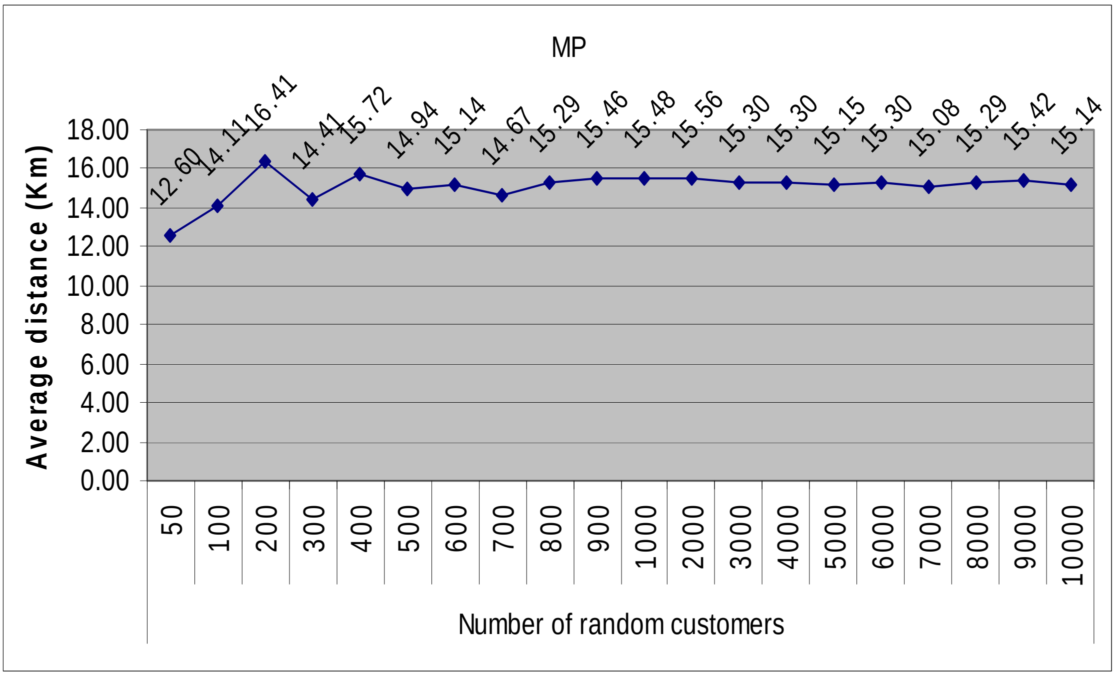

Figure 4.16 Average distance from a random customer to the nearest MP gas stations

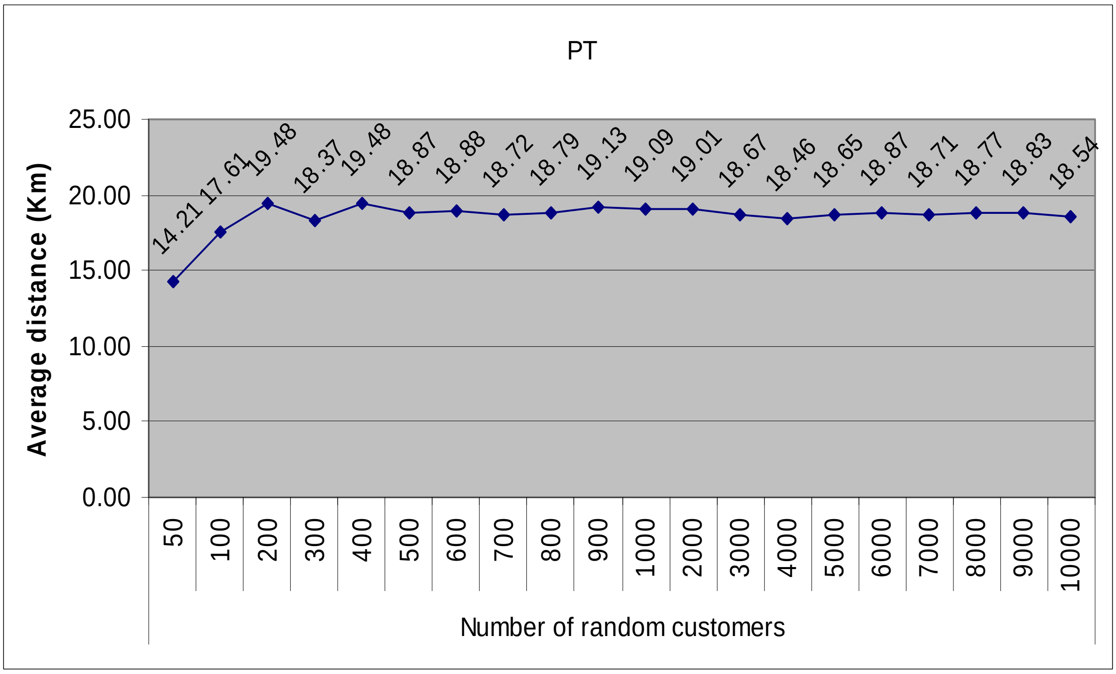

Figure 4.17 Average distance from a random customer to the nearest PT gas stations

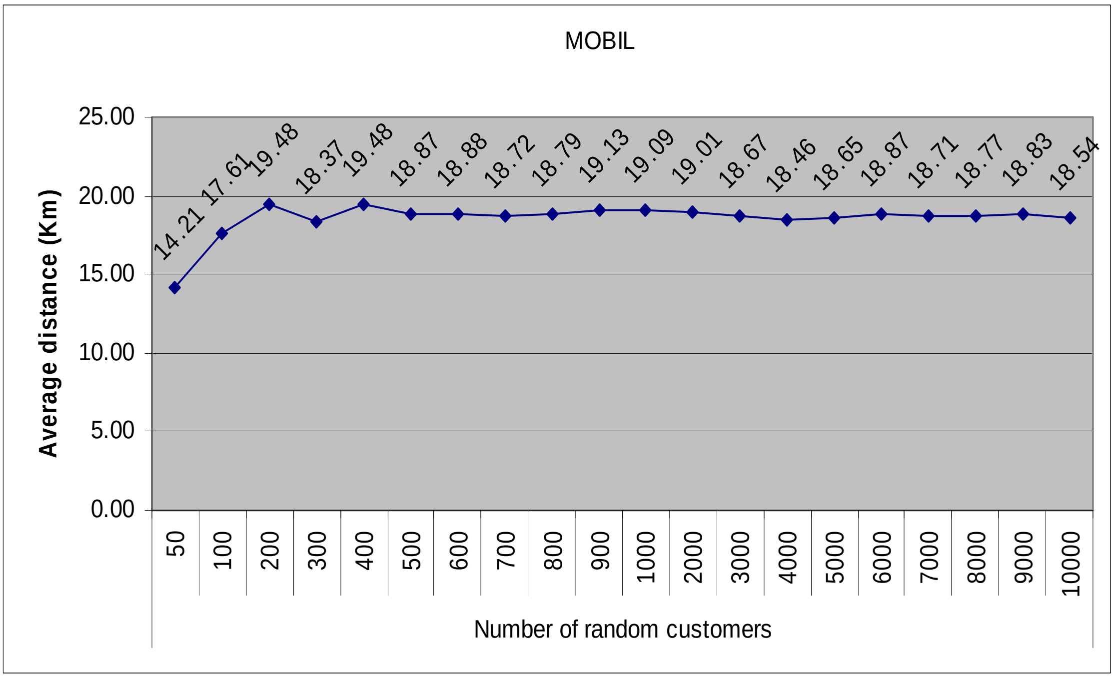

Figure 4.18 Average distance from a random customer to the nearest MOBIL gas stations

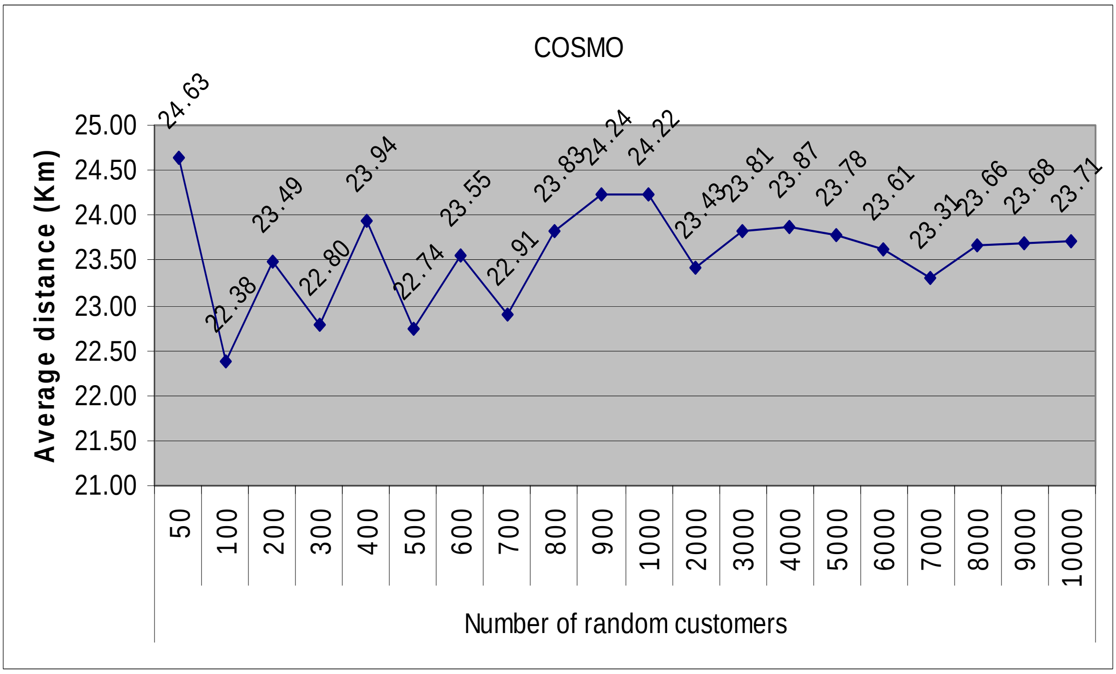

Figure 4.19 Average distance from a random customer to the nearest COSMO gas stations

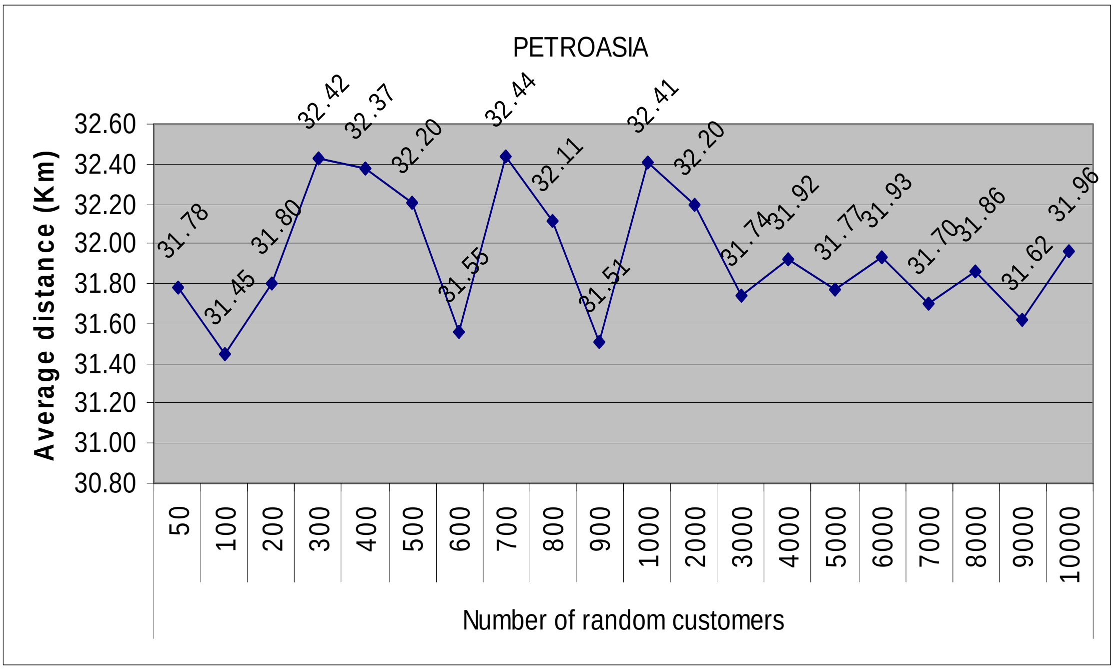

Figure 4.20 Average distance from a random customer to the nearest PETROASIA gas stations

The graphs indicated that during the earlier phase with 50-1,000 random customers, the average distances are going ups and downs irregularly. In other words, it is not in the steady state. Then, the researcher started to increase the number of customers gradually to reach 10,000 customers in order to determine the convergent point to the steady state. As shown in the graphs it may be concluded that 10,000 customers should be used as the reference in this random sampling because the average distance started to remain stable at 5,000 customers. Therefore, using 10,000 customers for random sampling would be rather safe to produce reliable results.

Alternatively, a smoother graph may be plotted. The distance is averaged over each step of the incremental number of a randomized customer, rather than at the big jump. In other words, the moving average of the successive distances is computed. The results are then plotted versus the number of random customers on the X-axis. ArcGIS is used to plot these graphs as shown in Figures 4.21-4.33.

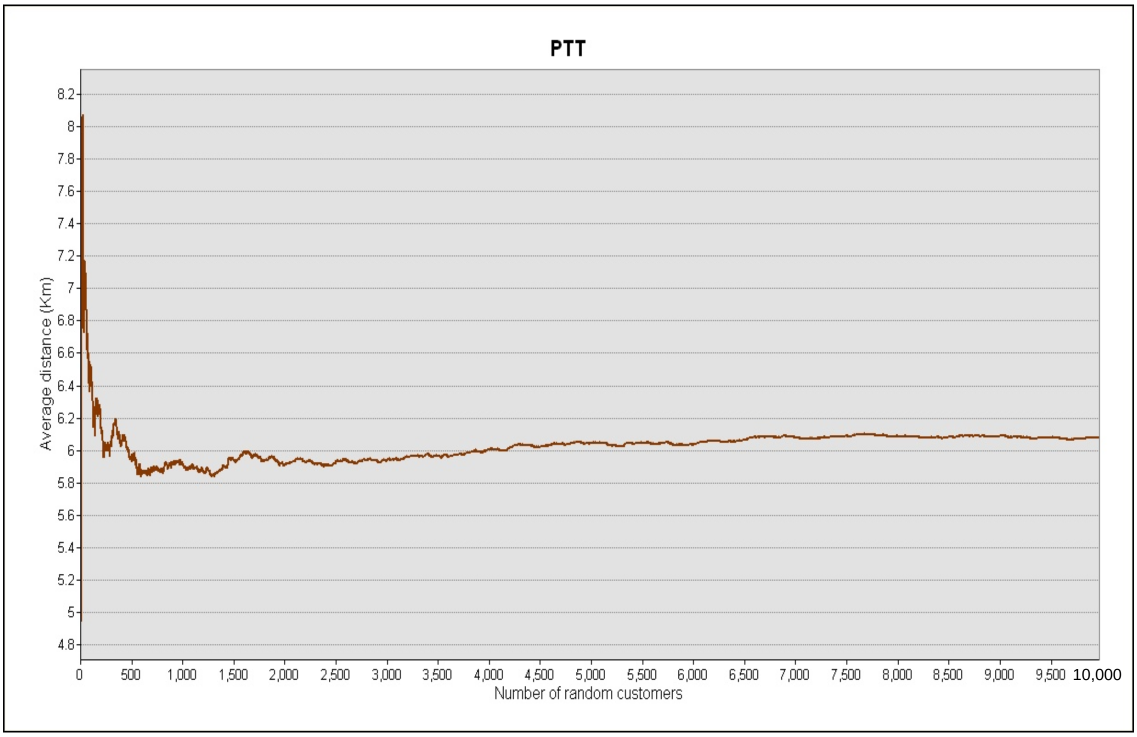

Figure 4.21 Average distance at different number of randomized customers, PTT case

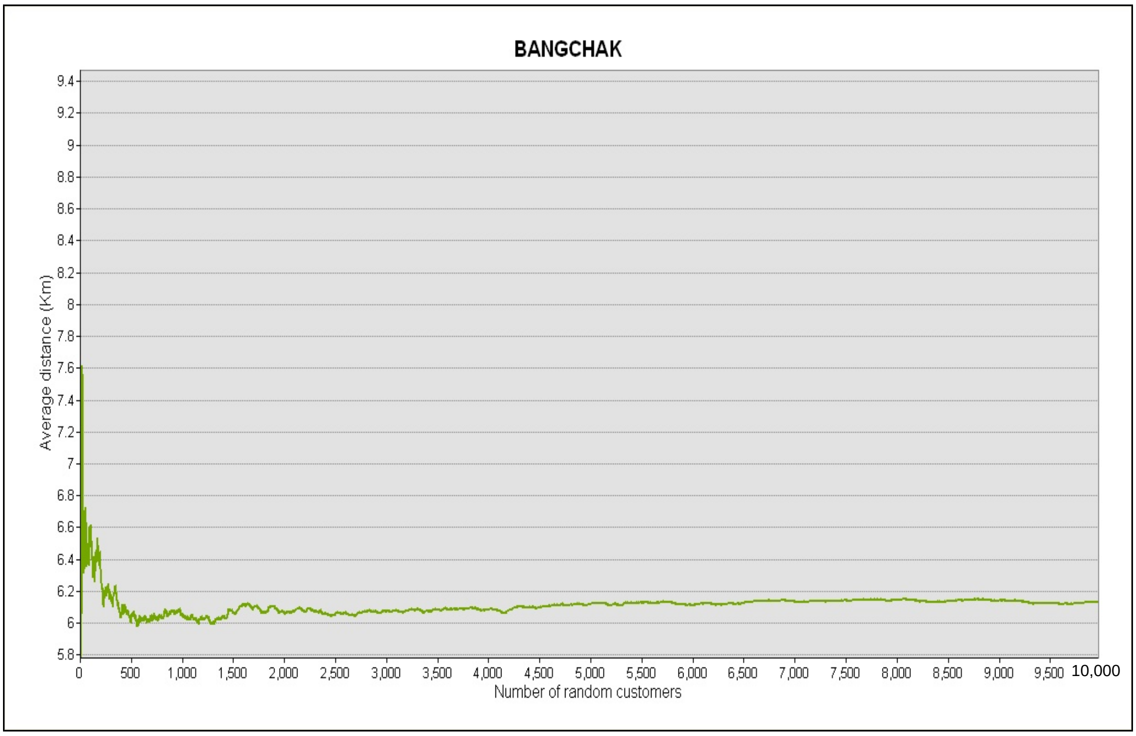

Figure 4.22 Average distance at different number of randomized customers, BANGCHAK case

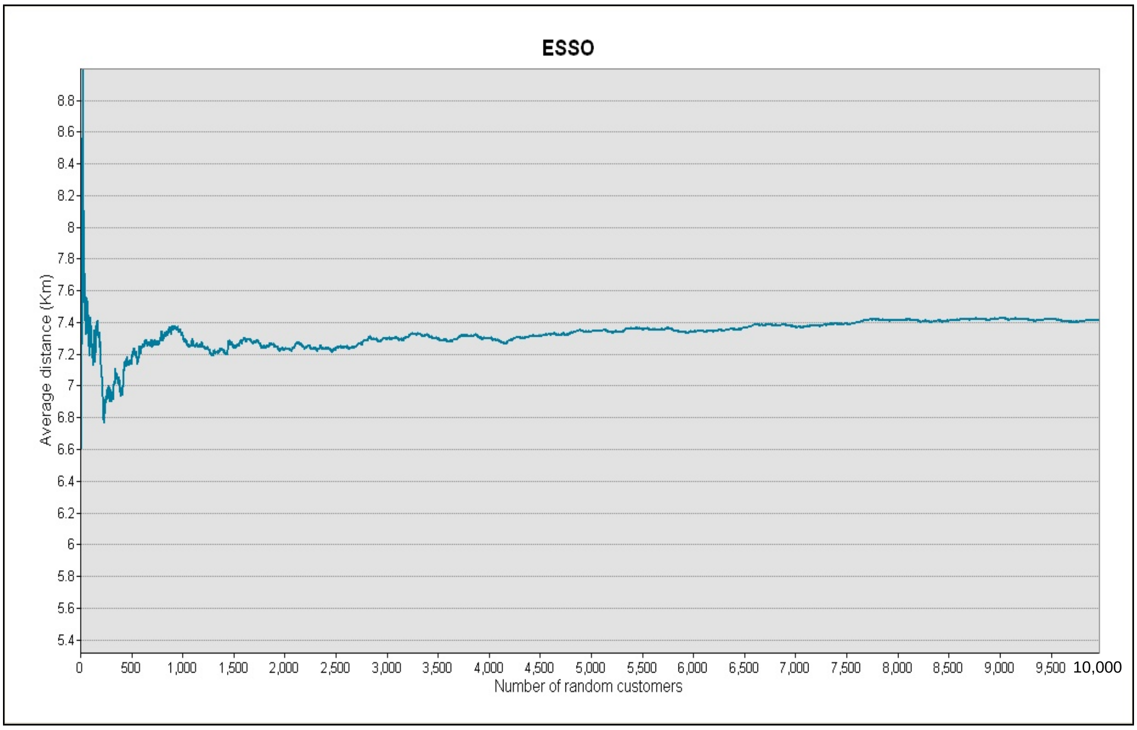

Figure 4.23 Average distance at different number of randomized customers, ESSO case

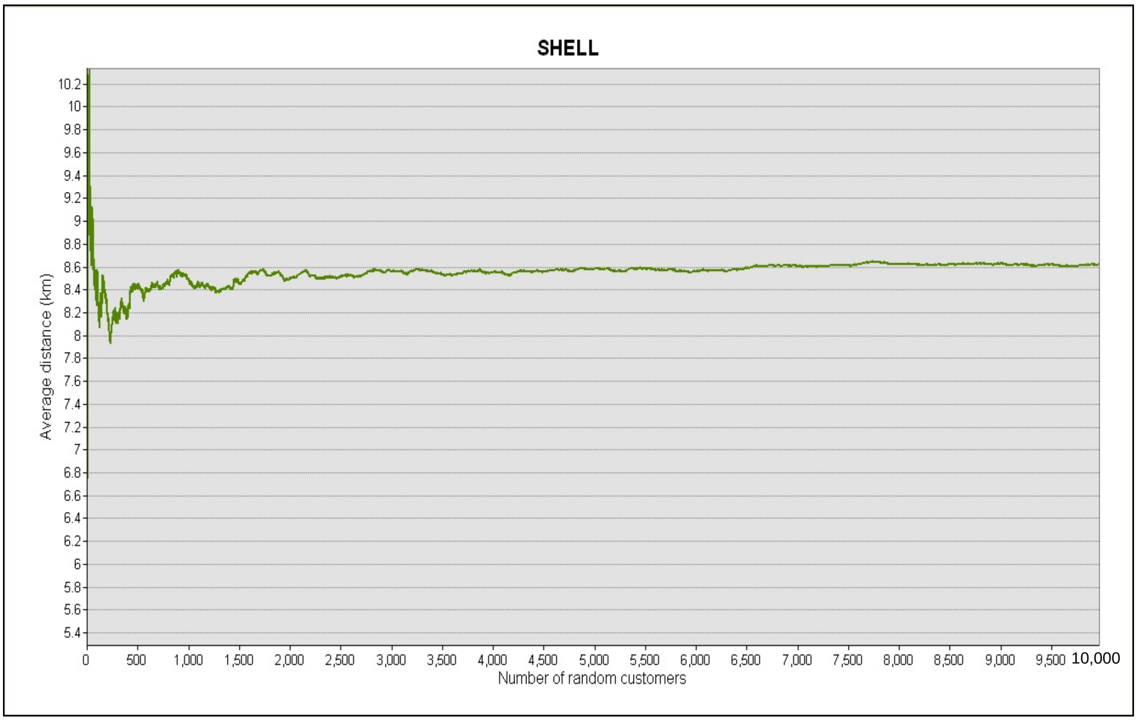

Figure 4.24 Average distance at different number of randomized customers, SHELL case

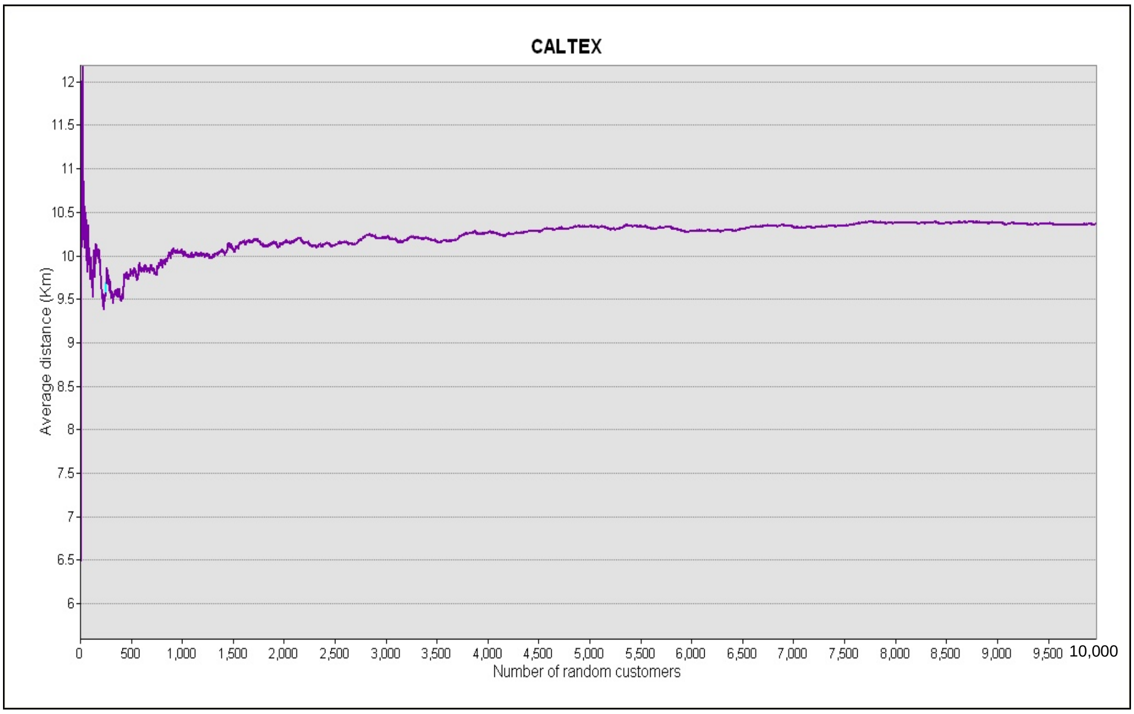

Figure 4.25 Average distance at different number of randomized customers, CALTEX case

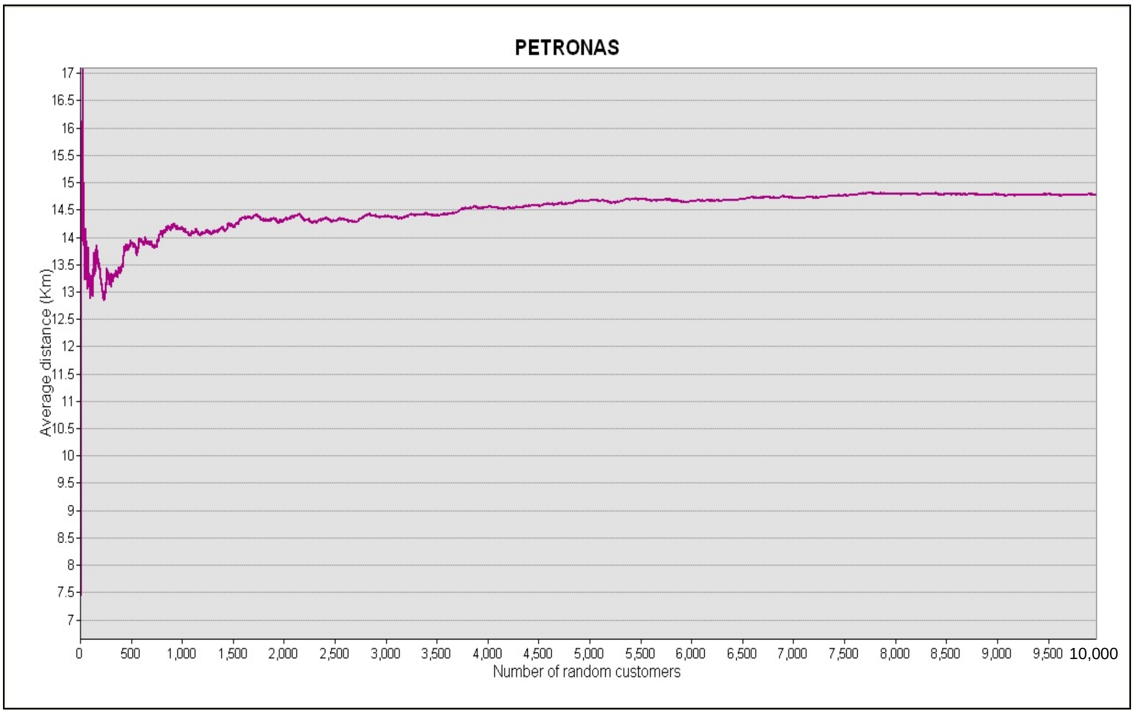

Figure 4.26 Average distance at different number of randomized customers, PETRONAS case

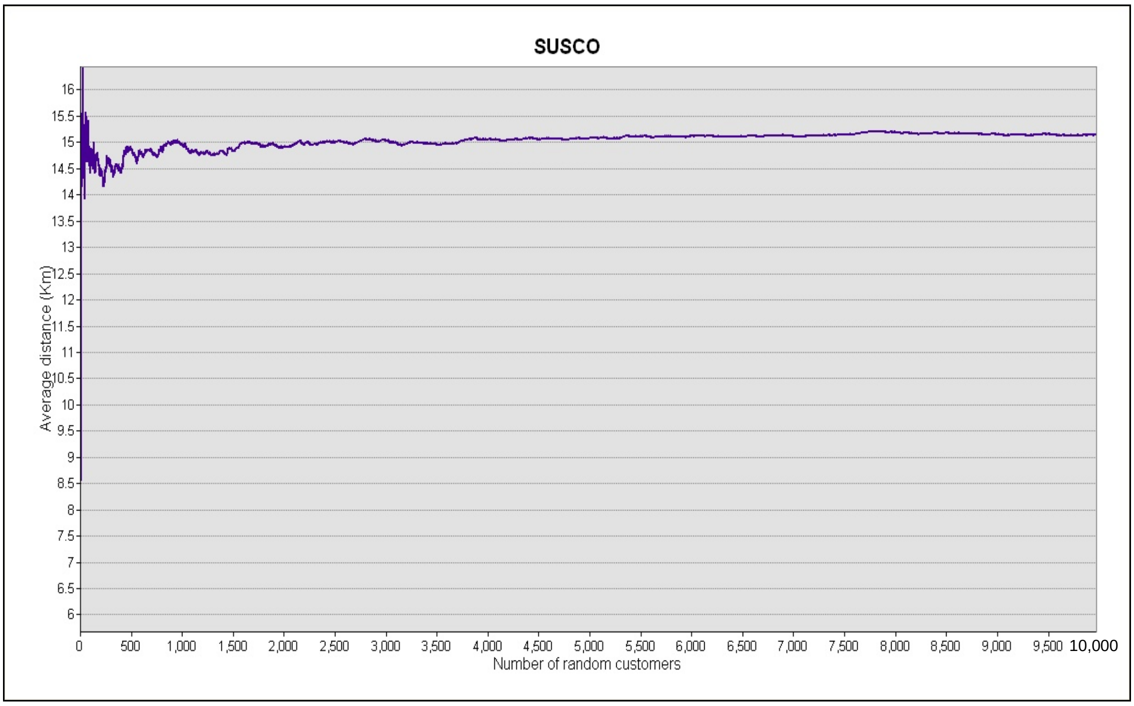

Figure 4.27 Average distance at different number of randomized customers, SUSCO case

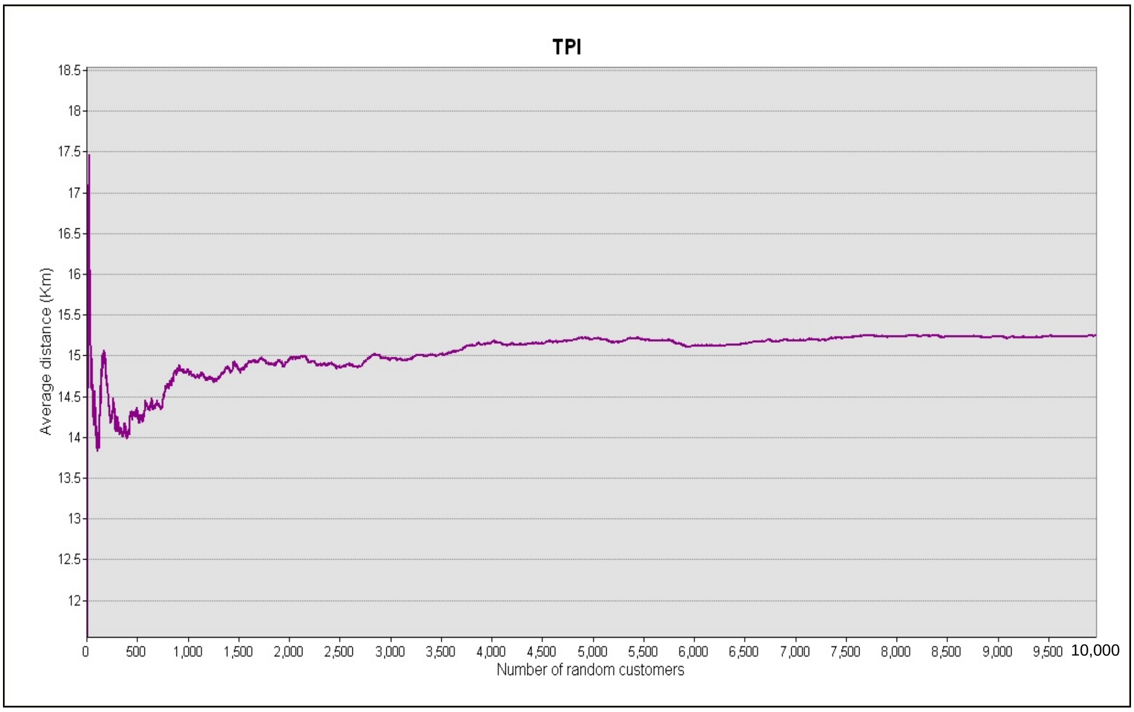

Figure 4.28 Average distance at different number of randomized customers, TPI case

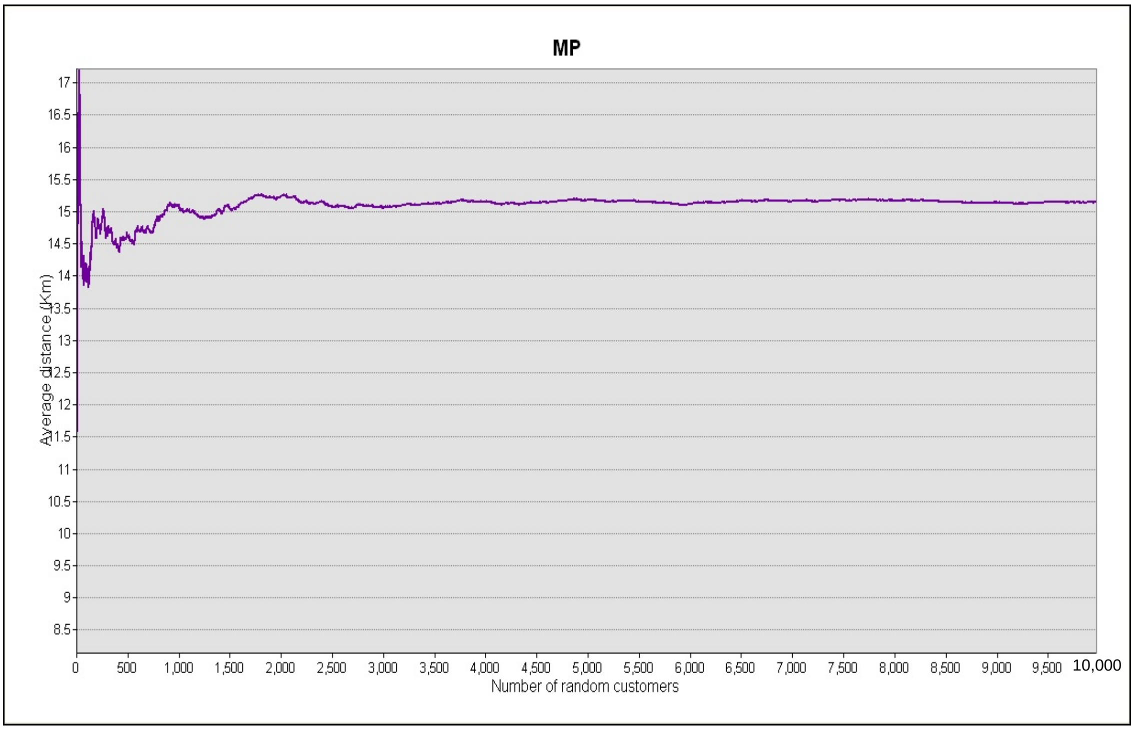

Figure 4.29 Average distance at different number of randomized customers, MP case

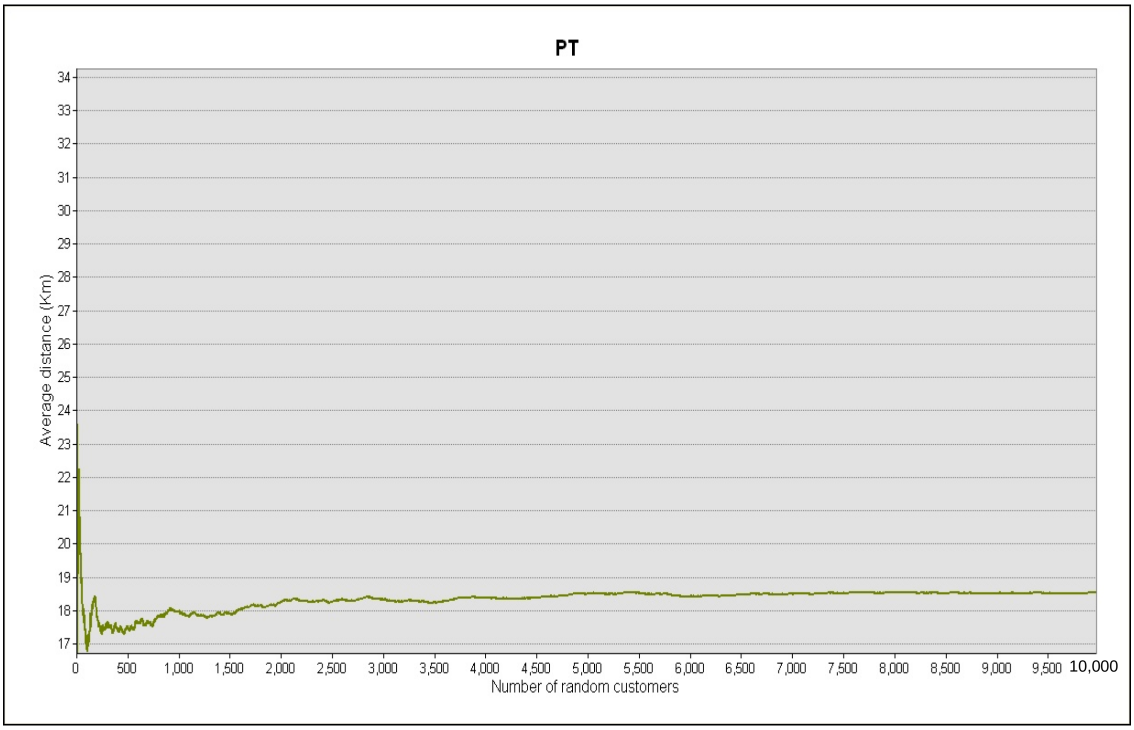

Figure 4.30 Average distance at different number of randomized customers, PT case

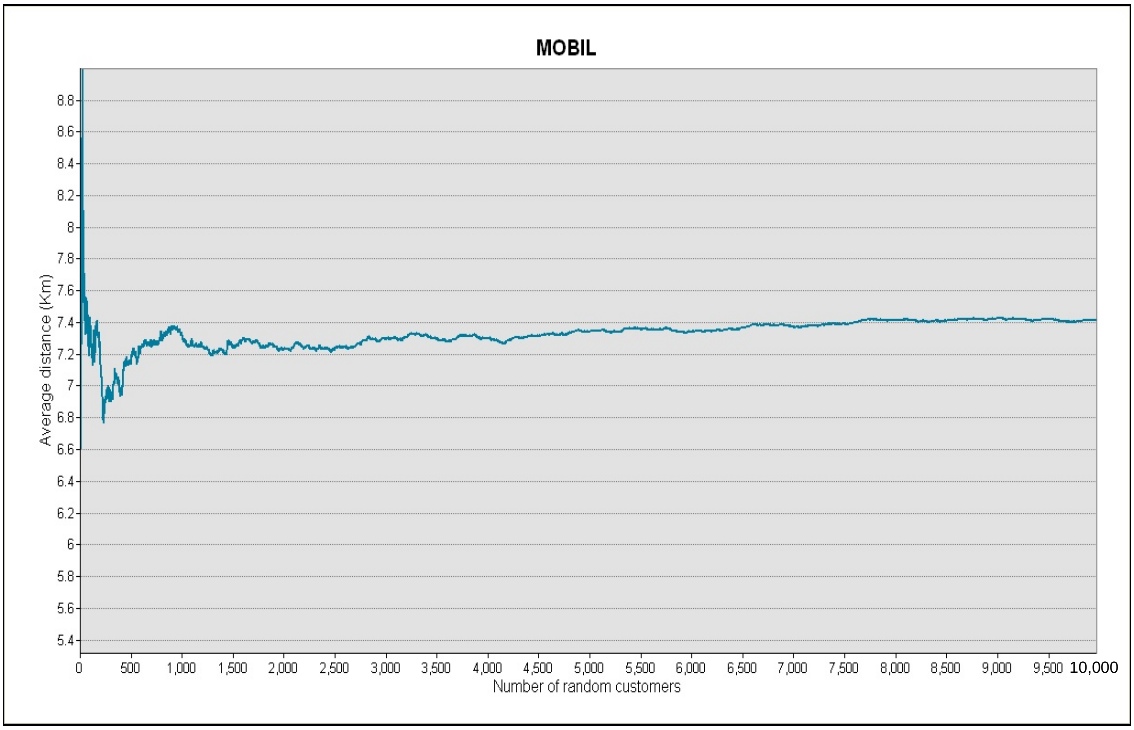

Figure 4.31 Average distance at different number of randomized customers, MOBIL case

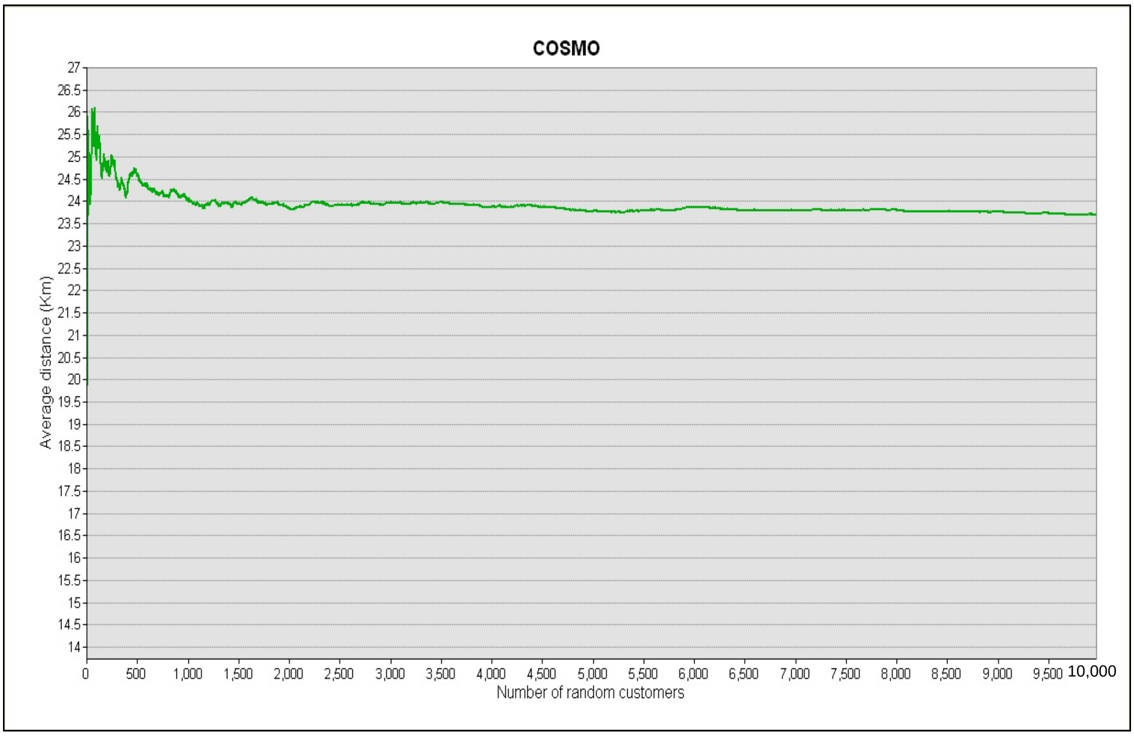

Figure 4.32 Average distance at different number of randomized customers, COSMO case

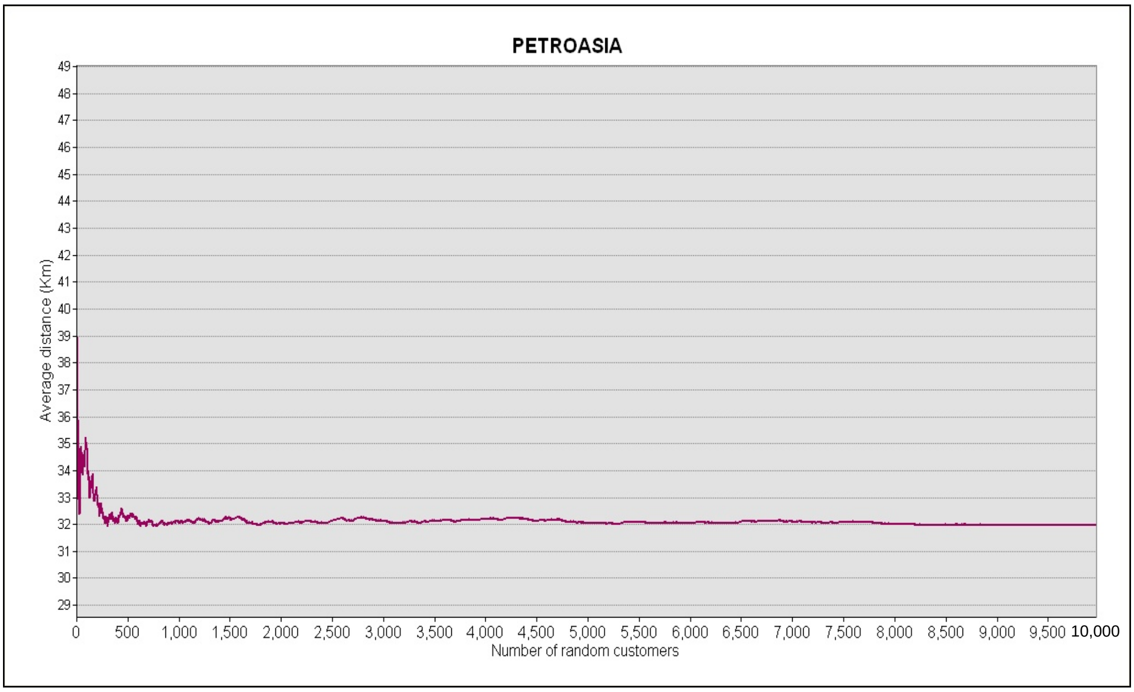

Figure 4.33 Average distance at different number of randomized customers, PETROASIA case

From Figures 4.21-4.33 revealed outcome from the cumulative average distance for each brand at various randomization. Experimental results indicated the necessities for using large numbers of customers in random sampling because small number customers provided non-stable results. Again, observe that the graphs in earlier phase (50-1,000 customers) fluctuated very much. Using the cumulative average distance yielded clear trend. By increasing the number of customers from 5,000 to 10,000, it was found that the graph started to remain stable in all brands. Therefore 5,000 customers should be used as the reference data. However, the researcher had increased the random samples to 10,000 customers just to ensure the convergent results.

4.3.2 Finding the Average Distance to the Nearest Gas Station of All Brands

The analysis for finding the average distance to the nearest gas station of all brands has a purpose to determine accessibility to the nearest gas station, regardless of brands, from customers' locations. This approach allows the researcher to assess the coverage of each gasoline brand within Bangkok metropolitan region. This information is useful for examining the relationship between the number of their gas stations and the service coverage.

Therefore, the researcher has analyzed levels of services of gas stations of all brands. By randomly selecting their locations, numbers of customers were increased gradually from 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 2,000, 3,000, 4,000, until 10,000 random customers as shown in Table 4.5

Table 4.5 Percentage share of a gasoline brand being the nearest gas station to the random customers

Brand	Number of Stations	Number of random customers									
		50	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**
PTT	311 (25.53%)	16.33	27.27	28.50	25.75	31.66	23.80	25.21	26.57	25.78	27.17
BANGCHAK	205 (16.83%)	24.49	31.31	32.50	24.41	25.63	29.60	26.54	26.43	27.53	27.73
ESSO	198 (16.26%)	14.29	12.12	9.50	11.37	13.07	13.60	14.52	14.43	13.39	11.36
SHELL	193 (15.85%)	14.29	11.11	11.50	9.70	7.04	9.00	11.02	9.00	9.01	9.02
CALTEX	148 (12.15%)	8.16	7.07	5.50	10.37	7.54	8.00	7.68	8.00	7.13	8.02
PETRONAS	74 (6.08%)	6.12	0.00	0.00	1.67	2.76	3.00	1.34	2.43	1.75	2.56
SUSCO	26 (2.13%)	4.08	2.02	3.00	1.67	2.51	2.80	2.34	2.43	3.25	2.00
TPI	21 (1.72%)	8.16	3.03	2.50	4.01	3.27	3.00	3.34	3.86	2.75	3.56
MP	17 (1.40%)	2.04	4.04	5.00	7.69	5.03	5.40	5.51	4.86	7.01	5.57
PT	14 (1.15%)	0.00	2.02	1.00	1.67	1.01	0.60	1.34	1.43	1.25	1.45
MOBIL	5 (0.41%)	2.04	0.00	1.00	0.67	0.25	0.40	0.50	0.29	0.50	0.67
COSMO	4 (0.33%)	0.00	0.00	0.00	1.00	0.25	0.60	0.33	0.29	0.50	0.56
PETROASIA	2 (0.16%)	0.00	0.00	0.00	0.00	0.00	0.20	0.33	0.00	0.13	0.33
Total	1,218 (100.00%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Notation: Shown as Percentage

Table 4.5 Percentage share of a gasoline brand being the nearest gas station to the random customers (cont.)

Brand	Number of random customers									
	1000	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
PTT	26.65	26.28	26.61	26.35	26.98	26.61	26.81	26.58	26.64	26.97
BANGCHAK	26.05	24.72	26.04	24.92	25.82	24.97	26.27	25.64	25.38	24.56
ESSO	13.43	15.45	12.50	13.75	13.52	13.74	12.77	13.73	13.29	13.48
SHELL	9.52	8.17	8.56	8.86	8.61	8.44	8.48	8.62	8.87	8.56
CALTEX	6.61	8.78	8.19	9.03	8.41	8.87	8.48	8.42	8.36	8.32
PETRONAS	2.20	3.11	2.14	2.38	2.64	2.46	2.30	2.29	2.32	2.35
SUSCO	3.21	2.81	2.74	3.14	2.62	2.95	3.23	2.88	3.11	3.22
TPI	3.01	3.56	3.54	3.99	3.79	3.65	3.74	3.40	3.87	3.81
MP	6.41	4.56	6.35	5.40	5.15	5.87	5.41	5.61	5.33	6.07
PT	1.50	1.00	1.87	1.30	1.32	1.17	1.38	1.33	1.57	1.45
MOBIL	0.70	0.25	0.53	0.35	0.40	0.47	0.34	0.61	0.36	0.44
COSMO	0.50	0.90	0.70	0.48	0.48	0.59	0.67	0.65	0.66	0.63
PETROASIA	0.20	0.40	0.20	0.05	0.24	0.22	0.13	0.23	0.23	0.14
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Notation: Shown as Percentage

From Table 4.5, the results from analyzing accessibility of customers to services of gas stations of all brands revealed that:

1) Number of gas stations affected accessibility of customers; the higher numbers of customers, the more chances that customers can use the services.

2) In order to achieve steady data of accessibility to gas stations, there need to have the greater random number of customers.

3) The percentage share does not change much as the number of random customers grows beyond 5,000.

4) Observe that the mean of distances tends to increases as the number of random customers increase. The trend is rather persistent with all gasoline brands. Possibly, this has something to d o with the distribution of the gas stations and randomized customers. In this study, the customers are generated by a uniform distribution. However, the location of gas station is spatially distributed, not necessarily uniform.

Figure 4.34 showed the graph of average distance based on the 10,000 random customers. It looks at average distance to the nearest gas station of each brand. There are gas stations that have the distance at less than 10 kilometers, namely, PTT (6.08 Km), BANGCHAK (6.14 Km), ESSO (7.42 Km) and SHELL (8.62 Km). Meanwhile the brand with average access distance between 10 to 20 kilometers consists of CALTEX (10.37 Km), PETRONAS (14.79 Km), MP (15.14 Km), SUSCO (15.14 Km), TPI (15.25 Km) and PT (18.54 Km). For the average access distance more than 20 kilometers, there are COSMO (23.71 Km), MOBIL (25.79 Km) and PETROASIA (31.96 Km) respectively. Findings from the figure indicated the tendency such that the more number gas stations likely leads to the shorter accessible distance.

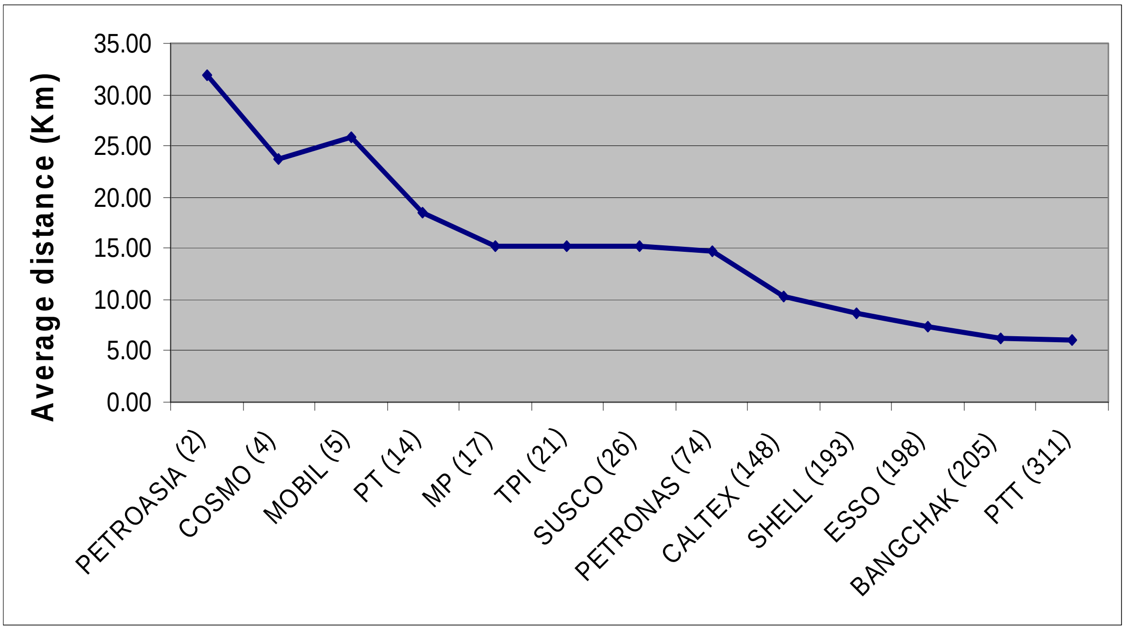

Figure 4.34 Average distance by gasoline brand based on the customer randomization at 10,000 customers

By performing the statistical analyses on the shortest distances to all brands, Table 4.6 summarizes descriptive statistics.

Table 4.6 Summary of the descriptive statistics on the average shortest distance of 10,000 randomized customers

Gas Station	Customer	Customer (%)	Min (Km)	Max (Km)	Average (Km)	SD (Km)	CV (%)
PTT (311)	2,690	26.97	0.01	23.39	4.04	3.32	85.91
BANGCHAK (205)	2,449	24.56	0.02	19.53	5.04	3.80	75.00
ESSO (198)	1,344	13.48	0.00	16.69	4.45	4.27	88.12
SHELL (193)	854	8.56	0.01	11.57	2.74	2.38	82.73
CALTEX (148)	830	8.32	0.00	12.53	2.98	2.04	69.00
PETRONAS (74)	234	2.35	0.04	7.21	2.16	1.18	69.01
SUSCO (26)	321	3.22	0.08	11.56	4.16	2.84	66.68
TPI (21)	380	3.81	0.00	10.82	3.87	2.25	57.61
MP (17)	605	6.07	0.17	15.42	5.02	2.91	62.48
PT (14)	145	1.45	0.17	12.95	4.51	3.20	75.54
MOBIL (5)	44	0.44	0.11	6.44	3.62	1.22	38.96
COSMO (4)	63	0.63	0.05	11.15	5.43	2.91	61.42
PETROASIA (2)	14	0.14	0.44	4.65	2.02	1.10	72.06

Notation: the numbers in brackets are the number of respective gas stations.

From Table 4.6, it is explainable that the level of accessibility to individual brands is influenced by the number of gas stations. That means the customers have better accessibility to the brand with higher number of gas stations. This experiment found that the highest accessibility brand was PTT, which could be the nearest gas stations accessed by 2,690 customers, or 26.97% of all customers, followed by BANGCHAK, with 2,449 customers (24.56%) and ESSO, with 1,344 customers (13.48%) respectively. The researcher has noticed that the number of PTT gas stations (311 stations) differ from number of BANGCHAK gas stations (205 stations) for 106 stations. However, numbers of customers that can access their stations differ for only 58 customers, which is rather marginal. Too many does not always guarantee much better accessibility. Meanwhile, if comparing with ESSO gas stations, number of gas stations of BANGCHAK was higher than ESSO (198 stations) for only 7 stations, but number of customers who can access these brands differ for as much as 1,105 customers.

The researcher provides two plausible explanations. First, it is possible that the location does matter the accessibility. BANGCHAK may be situated in the better locations which enable them to have shorter accessibility. Second, it is also possible that the distribution causes such a phenomena. Likes most convenient stores, the gasoline company may open a new station not always because of the desire to have better coverage, but often based on sale volumes or number of customers. The motivation is that the current station may not be able to be expanded due to space limitation. Therefore, to reduce the queue of customers, the oil company decided to locate the new station nearby to serve the excess customers. Consequently, the distribution of gas station does not change much as the number of PTT station grows.

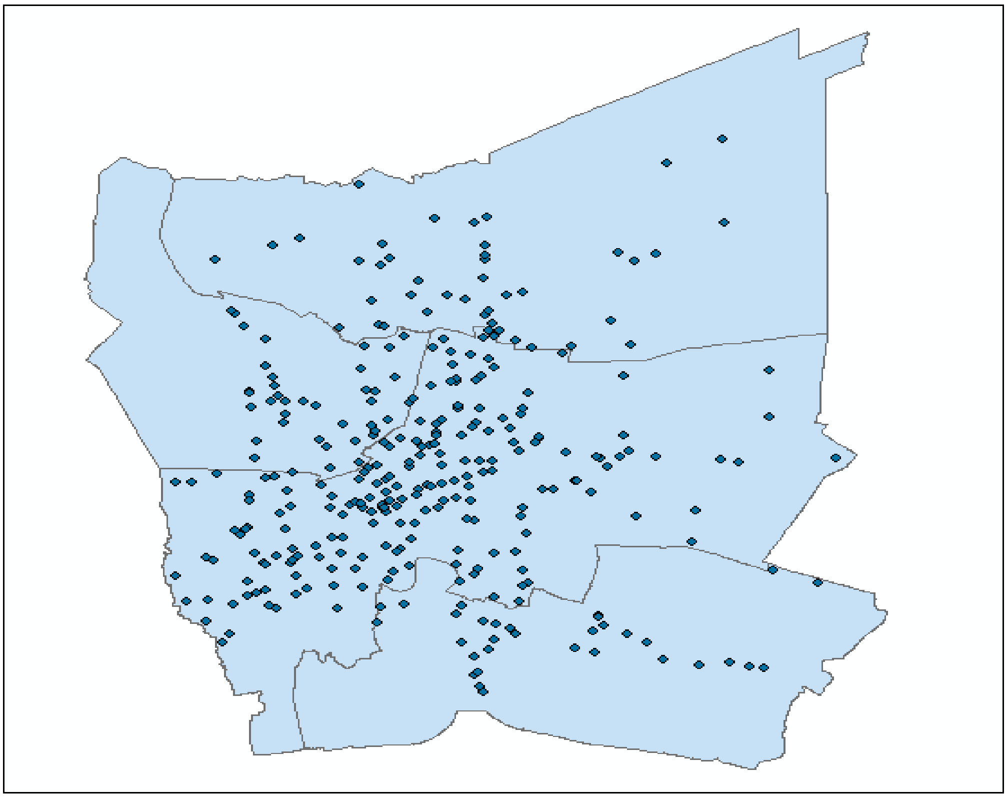

Figure 4.35 The spatial distributions of PTT gas stations

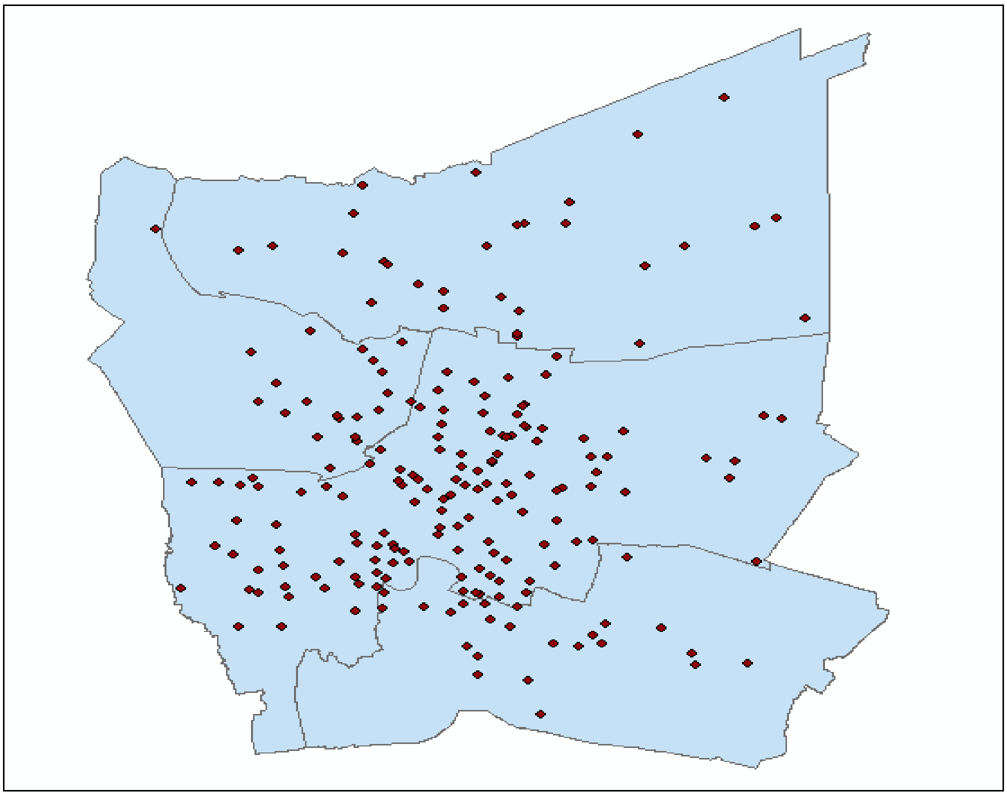

Figure 4.36 The spatial distributions of BANGCHAK gas stations

In Figures 4.35 and 4.36, the spatial distributions of PTT and BANGCHAK gas stations are displayed. It may be observed that the distance between PTT gas stations tend to be so close. To investigate this hypothesis, the researcher derived the distance matrices all gasoline brands by GIS and computed their overall means, SD and CV, as shown in Table 4.7

Table 4.7 Descriptive statistics of the shortest distances between gas stations

No.	Brand	Number of stations	Non-zero cells	Average (Km)	SD (Km)	CV (%)
1	PTT	311	96,410	28.33	14.39	50.79
2	BANGCHAK	205	41,820	29.55	15.32	51.84
3	ESSO	198	39,006	27.30	14.13	51.77
4	SHELL	193	37,056	22.85	12.42	54.35
5	CALTEX	148	21,756	24.79	12.84	51.81
6	PETRONAS	74	5,402	22.72	11.00	48.41
7	SUSCO	26	650	30.25	14.10	46.60
8	TPI	21	420	34.50	18.16	52.64
9	MP	17	272	37.93	20.78	54.79
10	PT	14	182	40.69	21.72	53.37
11	MOBIL	5	20	29.82	19.09	64.02
12	COSMO	4	12	51.32	17.20	33.51
13	PETROASIA	2	2	15.06	0.73	4.85

It may be observed that the average values of distance for PTT (28.33 Km) and BANGCHAK (29.55 Km) are rather similar. Even though, the number of PTT stations is much more than BANGCHAK. This may imply that the distribution of PTT stations is not spreading by considering the coverage. Many stations are actually close to each other.

4.4 Determination of SLA by Statistical Concept

For analyzing levels of service, the researcher used Microsoft Excel as a tool to calculate statistical measures. Subsequently, the statistical concept is applied to determine the SLA. Data of distances from customer locations to each brand of gas stations was imported into Microsoft Excel for the analysis. The summarized Excel file consisted of 8 columns as shown in Table 4.8. This example table presents distances from 10,000 random customers to their respective nearest PTT gas stations. Details of each column are explained below.

Table 4.8 Distance data for SLA determination based on 10,000 random customers, PTT case

Frequency distribution							
Distance to travel (Km)	Lower (Km)	Upper (Km)	Count Frequency	% Frequency	Cummalative % Frequency	Upper Bound %	Distance (Km)
8.35	0	1	506	5.07	5.07	5	0.99
1.15	1	2	1261	12.64	17.72	10	1.43
4.63	2	3	1279	12.82	30.54	15	1.81
8.60	3	4	1081	10.84	41.38	20	2.18
2.00	4	5	920	9.22	50.61	25	2.56
9.46	5	6	810	8.12	58.73	30	2.96
11.85	6	7	724	7.26	65.99	35	3.40
10.40	7	8	578	5.80	71.78	40	3.86
2.35	8	9	529	5.30	77.09	45	4.37
10.28	9	10	422	4.23	81.32	50	4.94
2.87	10	11	358	3.59	84.91	55	5.53
2.19	11	12	305	3.06	87.97	60	6.18
5.43	12	13	275	2.76	90.72	65	6.86
14.95	13	14	215	2.16	92.88	70	7.70
11.05	14	15	200	2.01	94.89	75	8.58
6.65	15	16	145	1.45	96.34	80	9.66
6.51	16	17	105	1.05	97.39	85	11.02
21.09	17	18	88	0.88	98.28	90	12.65
12.17	18	19	72	0.72	99.00	95	15.05
9.10	19	20	32	0.32	99.32	99	18.98
1.18	20	21	11	0.11	99.43	100	23.56
9.82	21	22	42	0.42	99.85		
2.51	22	23	9	0.09	99.94		
10.60	23	24	6	0.06	100.00		

1) Distance to travel

This column shows data on the average shortest distances from each customer location to the nearest gas station. The unit is in kilometer.

2) Lower

This column contains lower bound values of specified ranges of the distances. The distances are divided equally with a range of 1 kilometer. This lower bound values represent the minimum distance of the range that each customer location fell into.

3) Upper

This is the upper bound values of specified ranges of the distances. This upper bound values represent the maximum distance of the range that each customer location fell into.

4) Count Frequency

This column is used to count number of customers whose distances to the nearest gas station fell into the corresponding range. This value was obtained by using the COUNTIF function of Excel to calculate for number of distance values in the specified range from the respective cell in Distance to travel column. Each distance was recorded in each range of distance data. For example, if the distance from a customer to his nearest gas station is 1.5 kilometer, that distance is counted into the range (Lower bound – Upper bound) of 1-2 kilometers.

5) Frequency

This column presents percentages of distance values that fell into the range.

6) Cumulative Frequency

This column summarizes percentage of the range with percentages of all the above ranges. The last row ends up with the percentage of 100%.

7) Upper Bound

This column is the specification of the upper bound of the distance that used as the reference. This research will specify at the level 95% and 99%.

8) Distance

Distance is the column that shows the corresponding distance with respect to the specific upper bound, by using the function called PERCENTIL. The computation was carried out for upper bound between from 5% to 100%.

The researcher analyzes and estimates from the distance data of PTT gas station by using Microsoft Excel, at the upper bounds at 95% and 99%. These results are shown in the column named Distance. The results from this column can be used to estimate the SLA.

Table 4.9 Determination of SLA for PTT based on 10,000 random customers at upper bound of 95%

Upper Bound %	Distance (Km)
5	0.99
10	1.43
15	1.81
20	2.18
25	2.56
30	2.96
35	3.40
40	3.86
45	4.37
50	4.94
55	5.53
60	6.18
65	6.86
70	7.70
75	8.58
80	9.66
85	11.02
90	12.65
95	15.05
99	18.98
100	23.56

From Table 4.9, the researcher plotted the frequency distribution all data to present in a bar chart as shown in Figure 4.37 to facilitate the understanding. The bar chart consisted of two main parts namely:

1) Graph

The graph of distance data is represented in a bar chart format. X axis of the graph refers to average shortest distances from customers to gas stations, while Y axis refers to frequencies of customers that use the services.

2) Explanations

The explantions contained in the bar chart is used to explain relevant information, which is divided into 2 parts as follows:

- Average — This value is the average of distances from customers to each gas station.
- Upper bound — This value represents levels of upper bound that each gas station can give promise of its service to customers.

The next step is to find average distance from all random customers to their respective nearest each brand gas stations. The result from using statistics can be explained as follows;

- Minimum refers to the minimum shortest distance a that customer can access a gas station
- Maximum refers to the maximum shortest distance from a customer to the nearest a gas station
- Mean refers to the an average of the distances
- SD refers to the standard deviation of the distances
- CV refers to the coefficient of variation of the distances

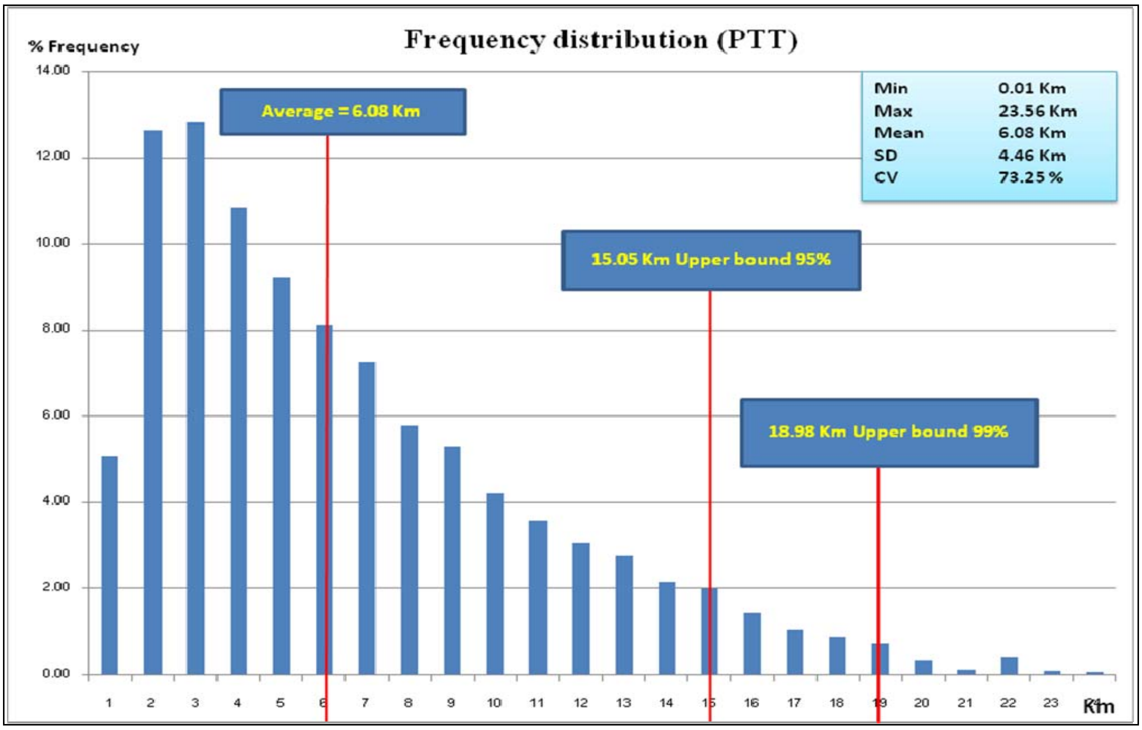

Figure 4.37 Frequency distribution of the average shortest distance to PTT gas stations based on 10,000 random customers

Results from the previous analysis could be used as reference data to determine the service level agreement at various upper bound for individual brands. That means gasoline companies can determine the distance at which they can guarantee services to their customers with pre-specified upper bound. The above procedures (Figure 4.37) were then repeated for analyzing distance data and determine the SLA for the remaining 12 gasoline brands. Analysis results are shown in bar chart format in Figures 4.38 to 4.49.

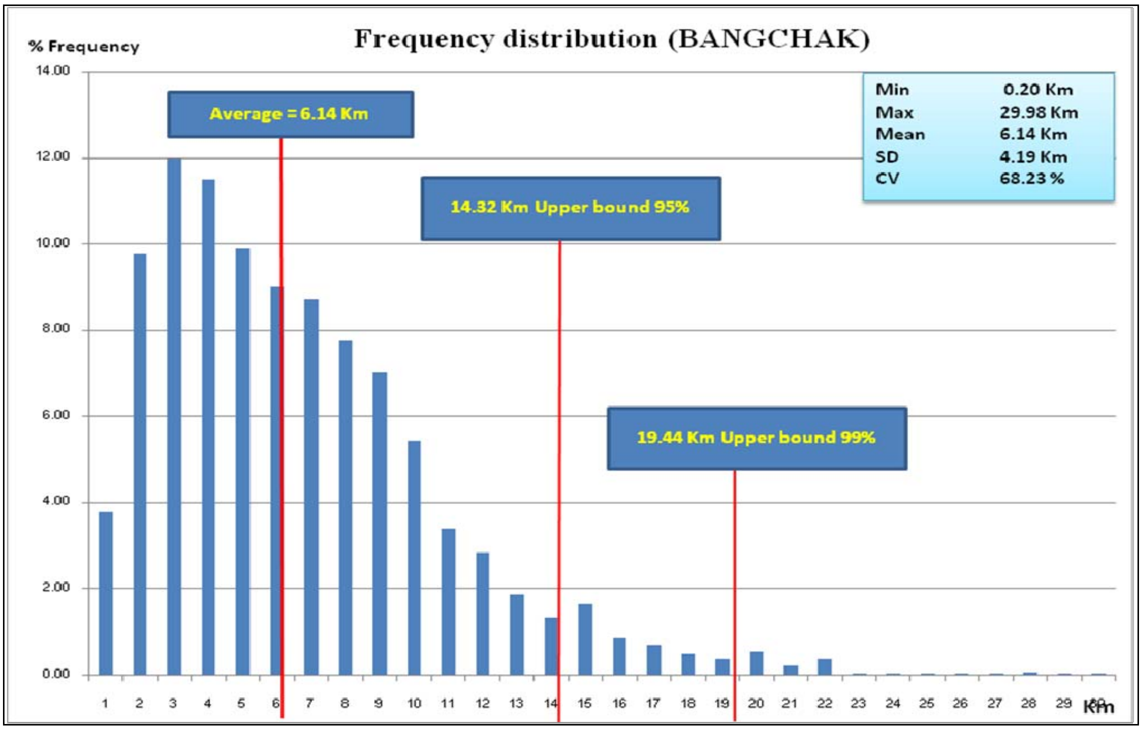

Figure 4.38 Frequency distribution of the average shortest distance to BANGCHAK gas stations based on 10,000 random customers

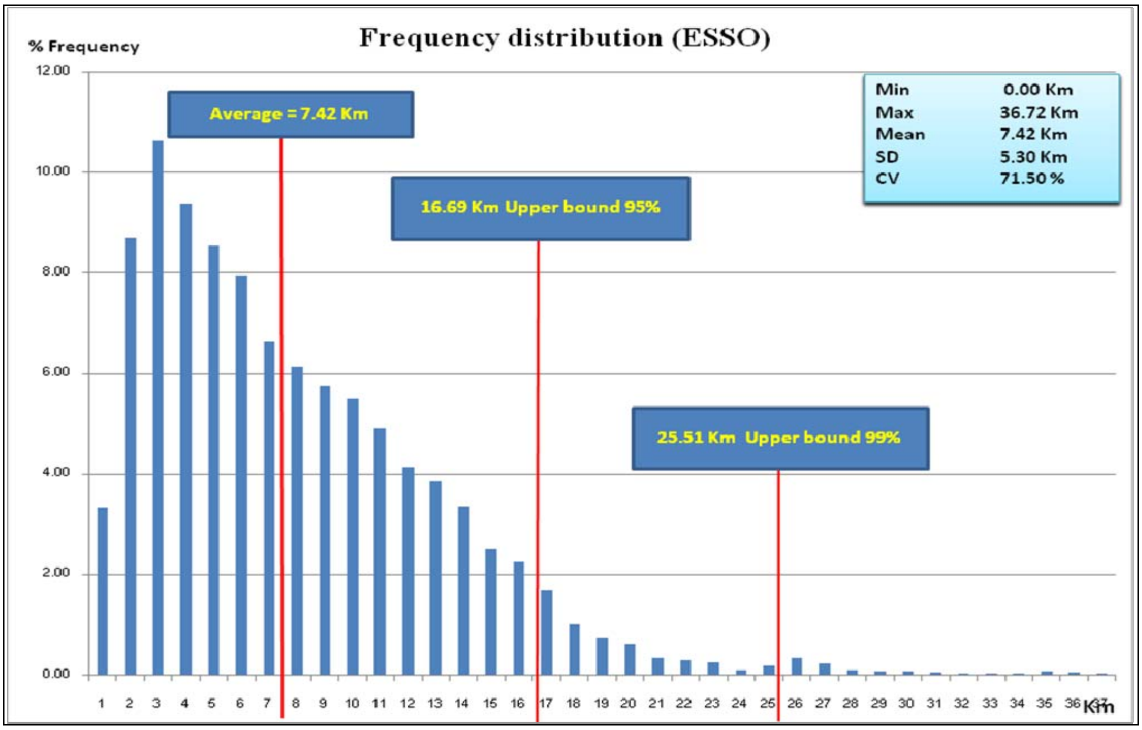

Figure 4.39 Frequency distribution of the average shortest distance to ESSO gas stations based on 10,000 random customers

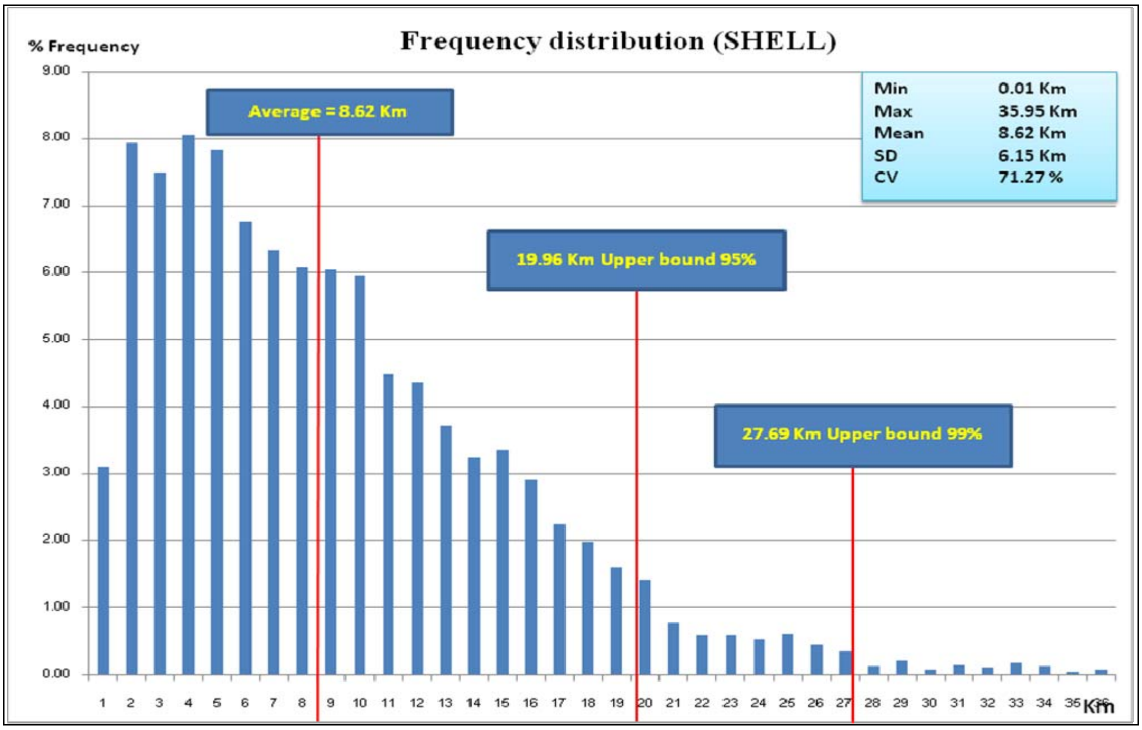

Figure 4.40 Frequency distribution of the average shortest distance to SHELL gas stations based on 10,000 random customers

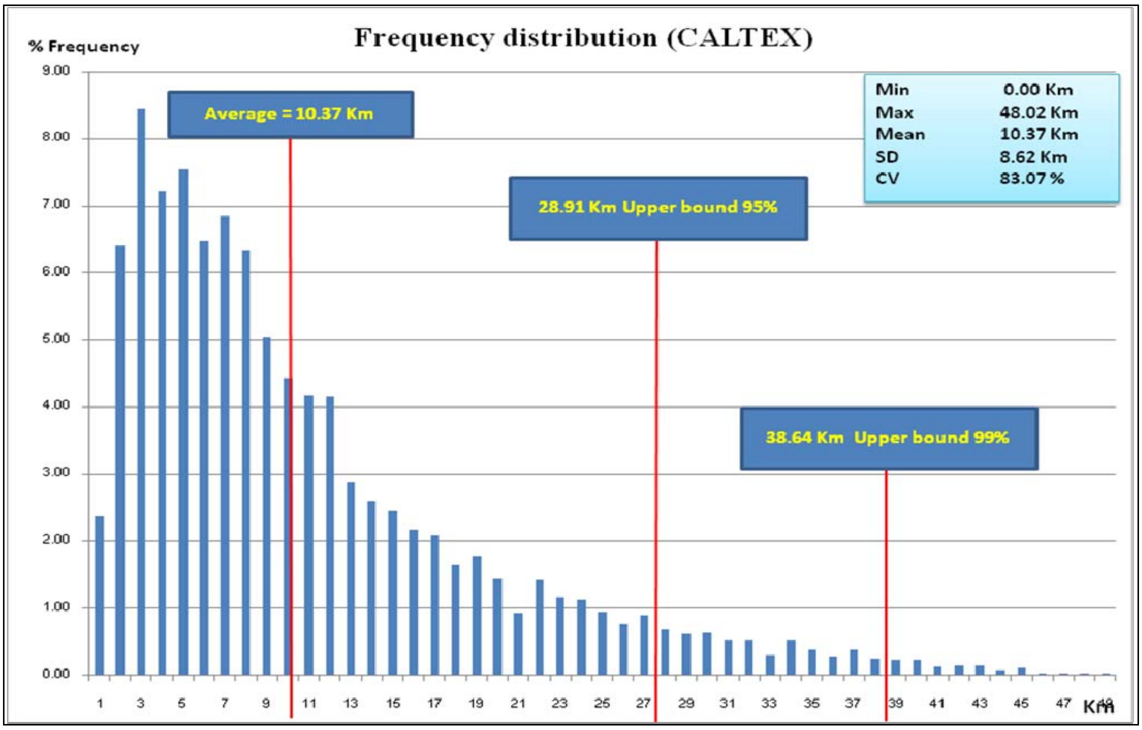

Figure 4.41 Frequency distribution of the average shortest distance to CALTEX gas stations based on 10,000 random customers

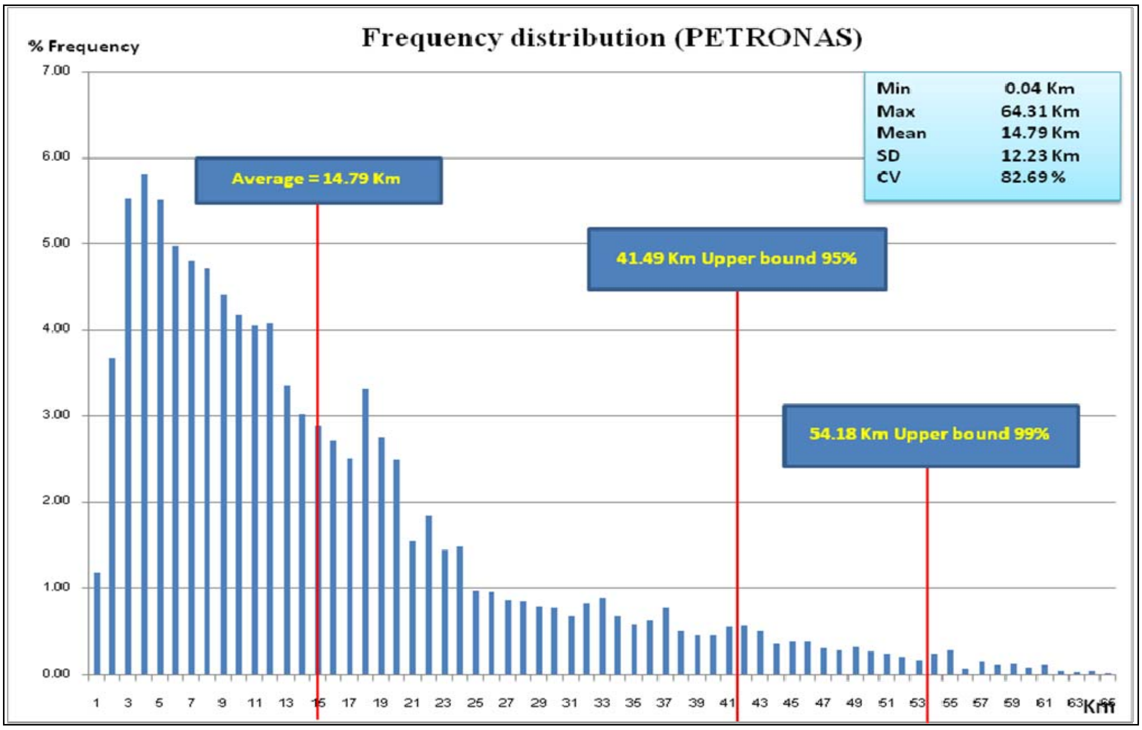

Figure 4.42 Frequency distribution of the average shortest distance to PETRONAS gas stations based on 10,000 random customers

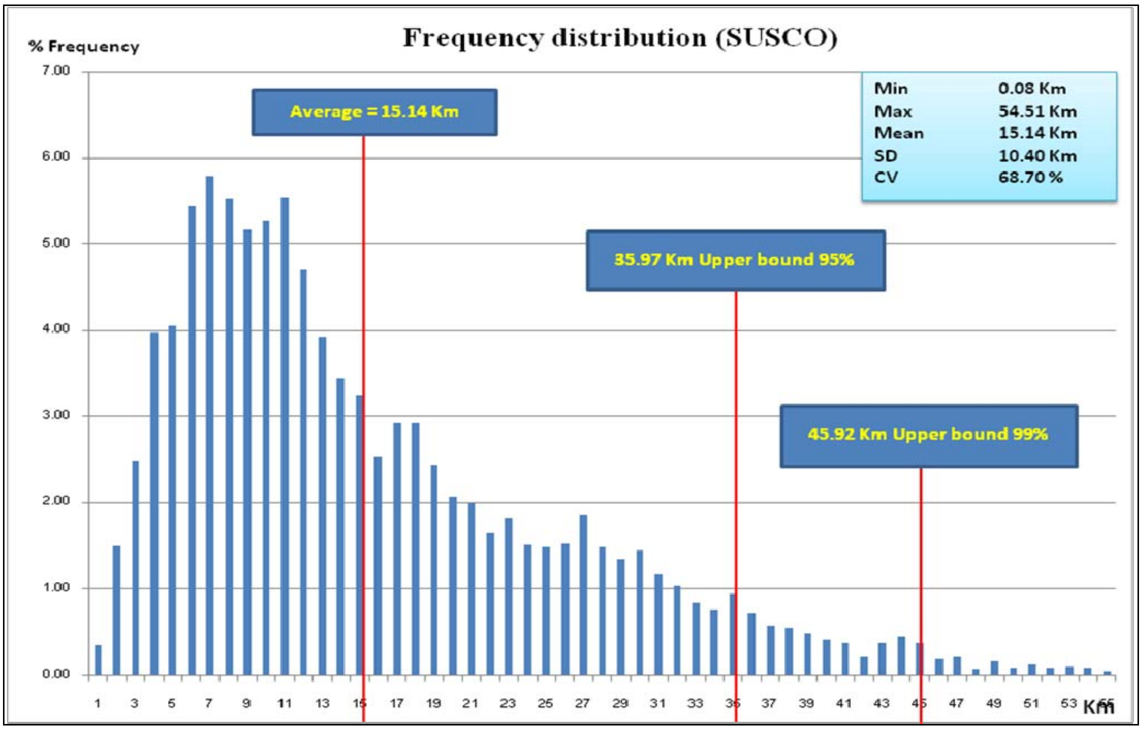

Figure 4.43 Frequency distribution of the average shortest distance to SUSCO gas stations based on 10,000 random customers

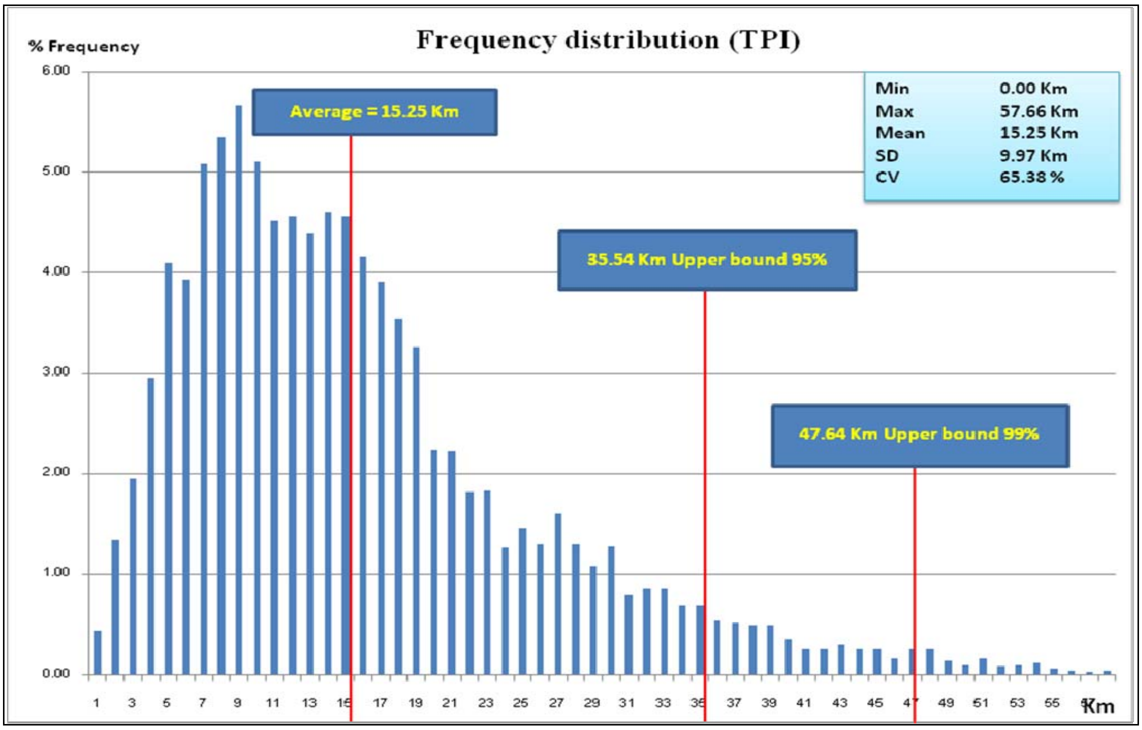

Figure 4.44 Frequency distribution of the average shortest distance to TPI gas stations based on 10,000 random customers

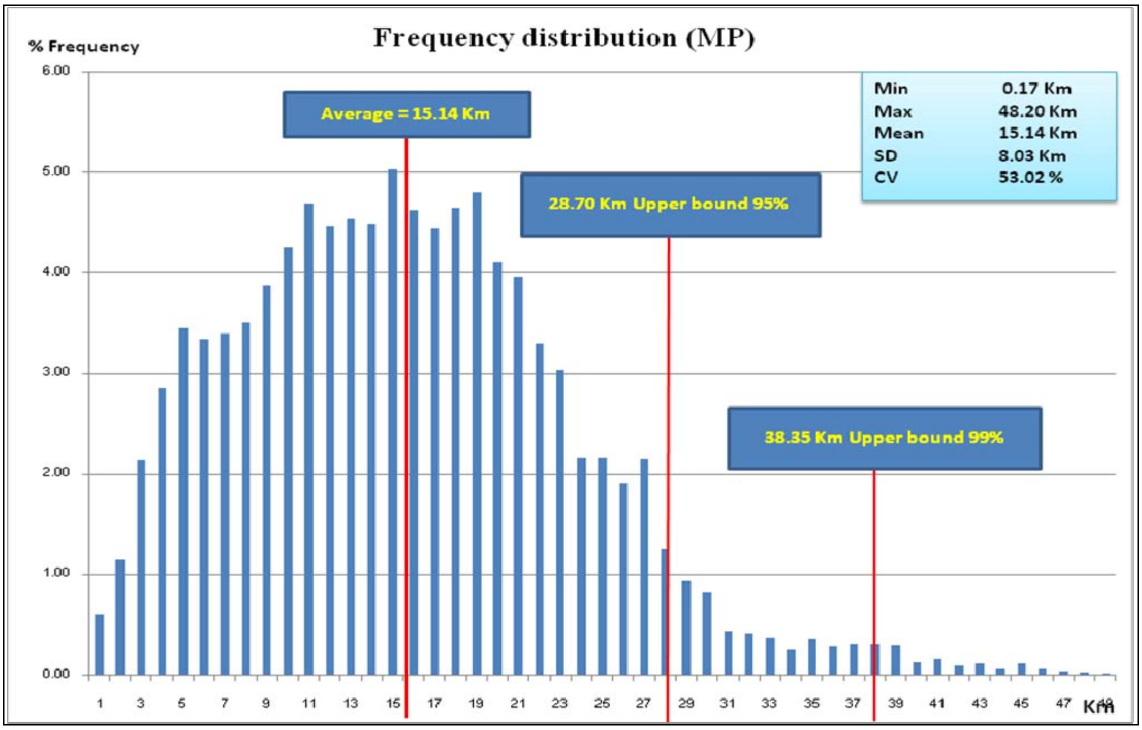

Figure 4.45 Frequency distribution of the average shortest distance to MP gas stations based on 10,000 random customers

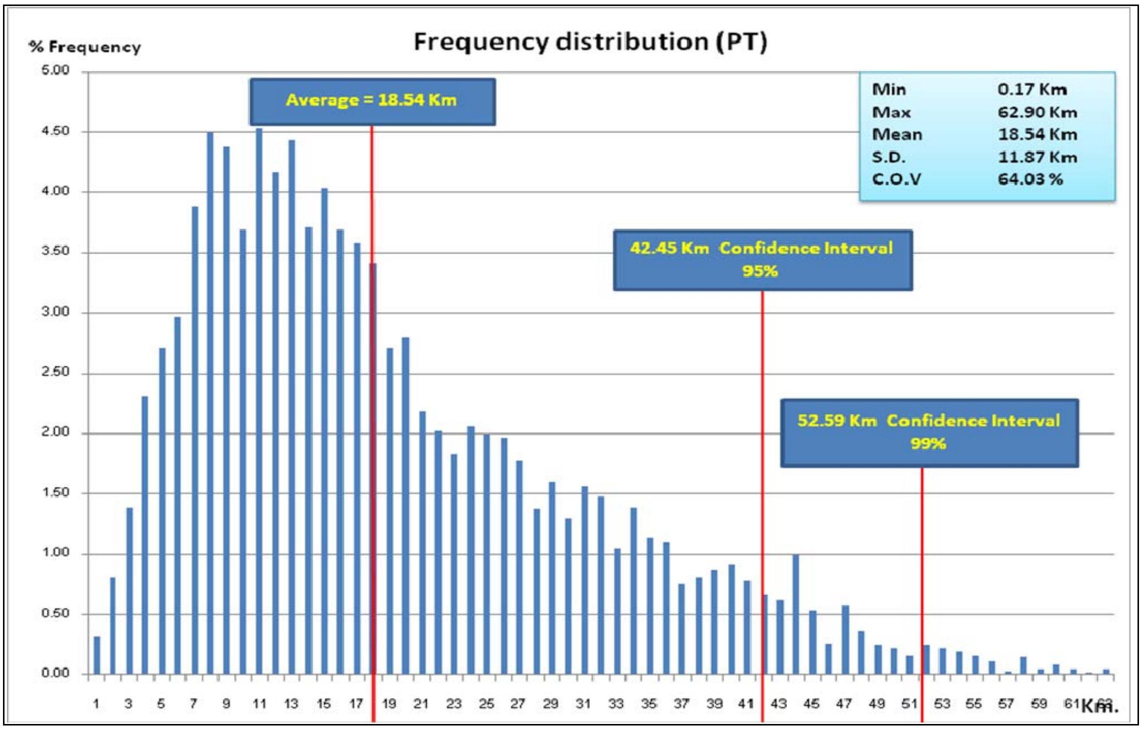

Figure 4.46 Frequency distribution of the average shortest distance to PT gas stations based on 10,000 random customers

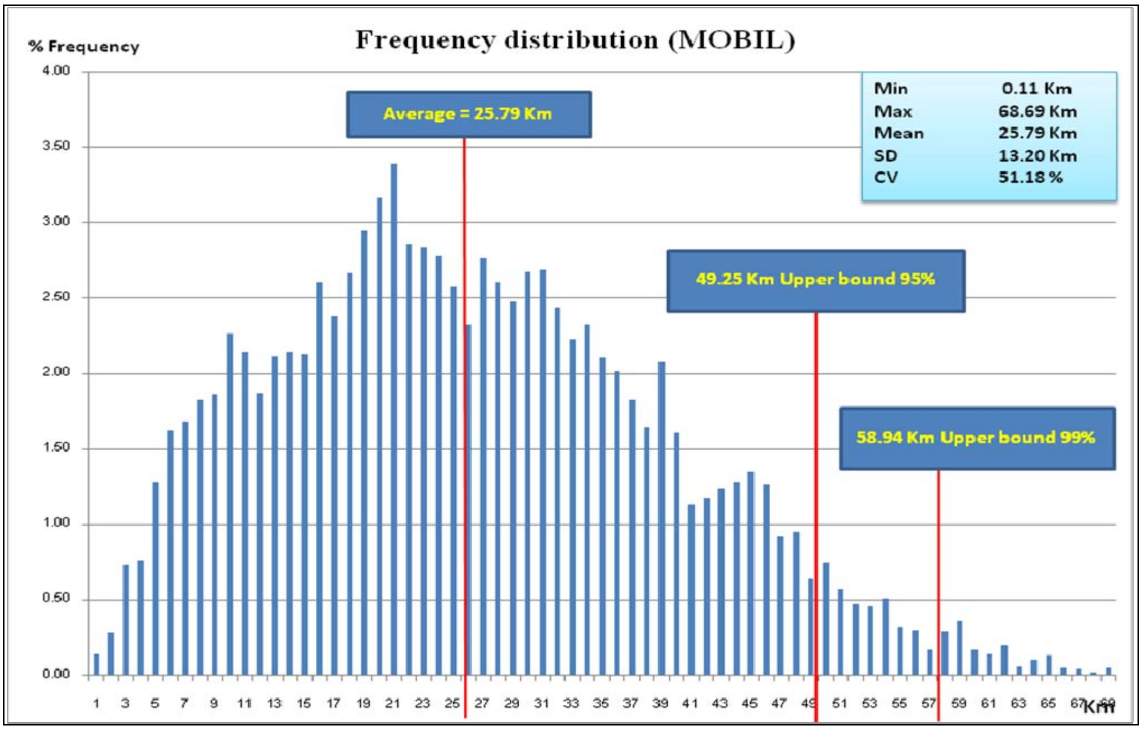

Figure 4.47 Frequency distribution of the average shortest distance to MOBIL gas stations based on 10,000 random customers

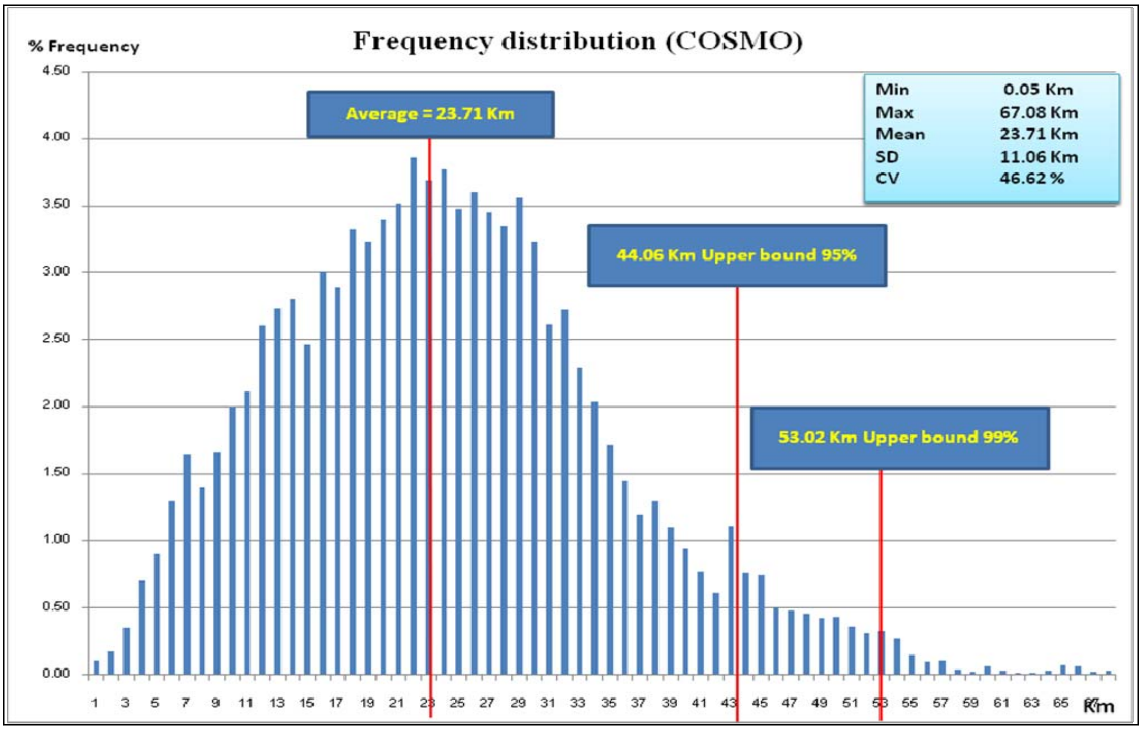

Figure 4.48 Frequency distribution of the average shortest distance to COSMO gas stations based on 10,000 random customers

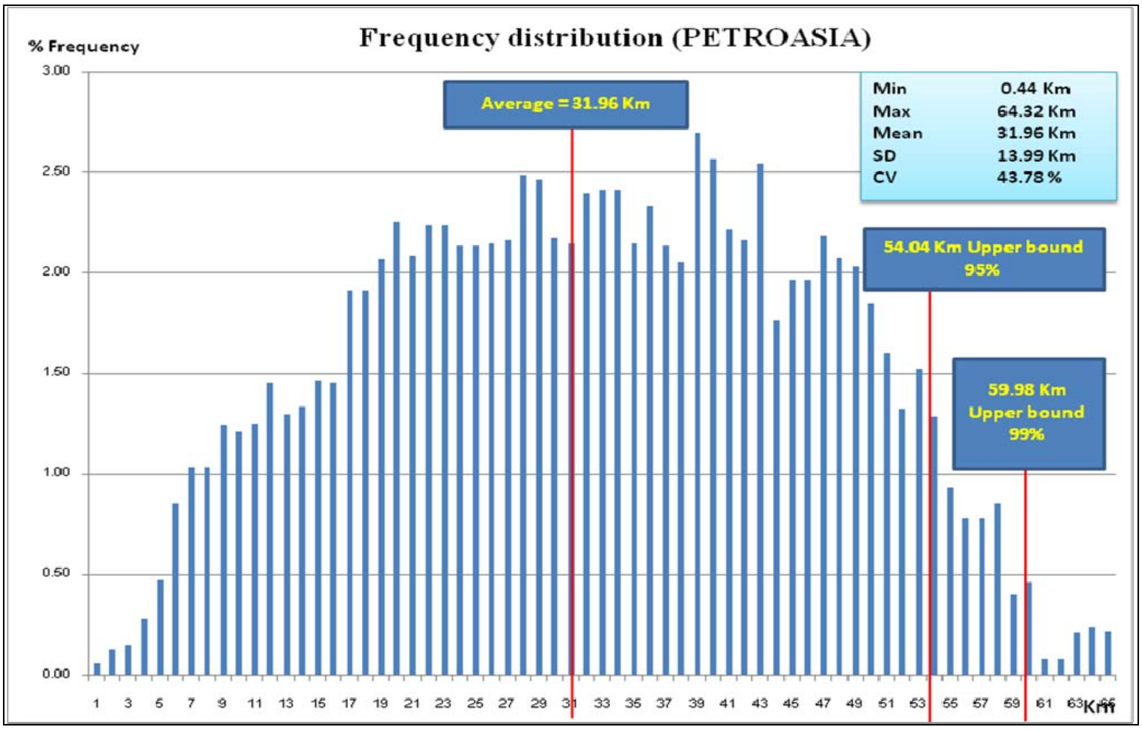

Figure 4.49 Frequency distribution of the average shortest distance to PETROASIA gas stations based on 10,000 random customers

Figures 4.37-4.49 showed the frequency distribution of the average shortest distance for all 13 different brands of gas stations. In this case, 3 brands were chosen for discussions, i.e., PTT, BANGCHAK and PETROASIA. For PTT and BANGCHAK, the findings indicated the spreading of data gathering at the left side. This implies that usually there is a gas station near the customer. It is coincided with the earlier analysis outcome that large number of gas stations provided average shorter accessible distance. Meanwhile, for PETROASIA in Figure 4.49, it shows the normal-like distribution. By having only 2 stations the data does not skew much. On average a customer may have to travel 31.96 Km. to find a PETROASIA gas station.

Table 4.10 summaries result from the analyses. The table compares SLA in term of accessibility, at the upper bounds of 95% and 99%, based on 10,000 random customers for all gasoline brands.

Table 4.10 Service Level Agreement of all gasoline brands

Brand	Number of stations	Average shortest distance (Km)	SD (Km)	SLA (Km) upper bound of 95 %	SLA (Km) upper bound of 99 %
PTT	311	6.08	4.46	15.05	18.98
BANGCHAK	205	6.14	4.19	14.32	19.44
ESSO	198	7.42	5.30	16.69	25.51
SHELL	193	8.62	6.15	19.96	27.69
CALTEX	148	10.37	8.61	28.91	38.64
PETRONAS	74	14.79	12.23	41.49	54.18
SUSCO	26	15.14	10.40	35.97	45.92
TPI	21	15.25	9.97	35.54	47.64
MP	17	15.14	8.03	28.70	38.35
PT	14	18.54	11.87	42.45	52.59
MOBIL	5	25.79	13.20	49.25	58.94
COSMO	4	23.71	11.05	44.06	53.02
PETROASIA	2	31.96	13.99	54.04	59.98

As an example, we explain results of PTT, the brand with the highest number of gas stations and PETROASIA the brand with the lowest number of gas stations. For PTT gas stations, the data showed that they may guarantee their service at 15.05 kilometers and 18.98 kilometers. That means, at the upper bounds of 95% and 99%, the average customer in anywhere within the area of Bangkok metropolitan region will always find a PTT gas station located no further than 15.05 kilometers and 18.98 kilometers from his/her location respectively. For PETROASIA gas stations, which had lowest number of gas stations, the guaranteed distance to service customers were 54.04 kilometers and 59.98 kilometers, at the upper bounds of 95% and 99% respectively. The customer in anywhere within the area of Bangkok metropolitan region will always find a PETROASIA gas station located no further than 54.04 kilometers and 59.98 kilometers from his/her locations. The distances are very long because PERTOASIA does not have many service gas stations (only 2) in Bangkok metropolitan region.

4.5 Summary

This research presents a concept and a calculation approach for determining service level agreement (SLA) in the road network. The researcher assume (for the case study of gas stations) that customers must travel on the transportation network and use services of gas stations within the area of Bangkok metropolitan region. The analysis method used Geographic Information Systems (GIS), statistical principles, and probability concept for calculation. Results show that distances from randomized locations of customers to the nearest gas stations reflect the level of accessibility to the gas stations and extent of their coverage, based on the assumption that each customer was pleased to use gas service of any brand. However, more does not always guarantee significant higher accessibility. The result from assessing levels of services of gas stations of each brand found that the location of gas stations is also important in determining their service level agreement.

CHAPTER V
CONCLUSIONS

Standard service is crucial in service-related businesses. Gas stations are considered as business that provided services to customers that involved both service providers and service receivers. Because each customer had different demand, it is necessary to apply SLA for referencing both service providers and receivers. This research assessed the accessible distance through the application of GIS and the use of statistical approach to find the distance to gas station by conducting the analysis for each brand and all brands.

Chapter 1 described the rationale of this thematic paper, the study objectives, scope of study as well as expected results. Chapter 2 explained the meaning of SLA as a contract between providers and clients. SLA has been widely studied in many related researches. Chapter 3 presented the methodology for determining the service levels by using gas stations as the case study. The transportation network and other related data of Bangkok metropolitan region were made available from the transportation FDGS. The customers' locations were determined randomly by GIS tools. The accessibility in terms of the shortest distance from a customer to a gas station was calculated by using the Network Analyst. The resulting shortest distances were analyzed by statistical methods to obtain the SLA at various upper bounds. In chapter 4, results from the case study were explained and discussed. The SLAs in terms of the accessible distance were calculated at the upper bounds of 95% and 99%. In this last chapter, the thematic paper is concluded.

5.1 Determination of Service Level Agreement (SLA) by Geographic Information System (GIS) and Statistical Concept

This research is aimed to study the computation of Service Level Agreement (SLA) with its applicability in many businesses as long as they possess similar basic characteristics. In the study, the gas station was used as a case study and the SLA is determined in terms of average shortest distance to the station on the road network. The shortest distance is computed by using GIS technology. In order to obtain the stable results, a large number of customers were randomly generated, varying from 50 to 10,000. The results seem to convert at samples above 5,000 based on series of average shortest distance. The statistical concept is applied to analyze the average distance at certain level of upper bounds of 95 and 99%. The results are called the SLA. Regarding the experiment, three major outcome can be drawn.

1) Numbers of customers and gas stations affected the distance for getting services. In other words, small numbers of customers' random sampling may result in the non-stable accessible distance as being seen in Chapter 4 by the left-skewed frequency distribution. By gradually increasing numbers of customers, the average distance tends to convert, hence, it is in the steady state. Random sampling of 5,000 customers may be enough for use as the referencing data. However, the researcher kept increasing the number of customers to 10,000, in order to observe the graph's direction. It is clearly observed that over 5,000 customers, the average distance are not different very the much. This confirmed that 5,000 samples are sufficient for the simulation.

2) In the case study of gas station, the results showed that, the more numbers of gas stations leads to the shorter average accessible distance. Among 13 brands of gas stations, PTT had the most numbers 311 stations. After assessing SLA and probability, the average distance was 6.08 kilometers which is the smallest average distance. The researcher used the upper bounds at 95% and 99%. With PTT, the SLA were 15.05 and 18.98 Kilometer at the upper bounds respectively. They may be used to reference and guarantee services at PTT service stations.

3) Large numbers of service stations increased the customers' accessibility. It was found that PTT had the most numbers 311 service stations, followed by 205 BANGCHAK stations. For random sampling at 10,000, customers the percentage share of a PTT stations being the nearest gas station to the random customer would be 26.97% as compared to 24.56% of BANGCHAK. Interestingly, PTT has 106 more service stations than BANGCHAK but only yielded the difference of 2.41% which considered quite low. Perhaps, PTT does not need further aggressive

branch expansions in the Bangkok metropolitan region because the increasing level of SLA is diminishing. Instead, PTT may focus its strategy on improving the service variety and quality at its gas stations.

5.2 Applications of the Proposed Method to Determine SLA in Other Businesses

The application of the developed method to determine SLA in other businesses involves the distance data. Any business that distance to the customer matters, the proposed method may be applied. Post boxes, ATM, convenient stores and banking are some business examples. Determination of SLA in such businesses would yield useful data, especially the sufficient numbers of service stations, and approximate market share. The application of SLA concept may enhance the competitive advantage of the business over the competitors.

5.3 Cautions and Suggestions

The researcher had gathered the following observations while conducting this research;

1) The customers' locations derived from randomly sampling could be in the area with no road access. It was found that Nonthaburi had a specific area, called Ko Kred which is an island in the middle of the river that can be accessed only by boat. Then, the interpretation of results is generally true for area with road accessibility.

2) Sometimes the locations of random customers are at the boundary of the study area, which connected to surrounding provinces namely Pra Nakhon Sri Ayuddhaya, Nakhonpathom, Nakhon Nayok, Chachoengsao, and Samutsakorn. Even though there were roads connecting these areas, they are out of the consideration due to the defined study area. Therefore, customers whose locations were in that bordering area may not have any roads to accessing a gas station or they have to travel city

bound to find a gas station. Although this seems to be unrealistic situation, such occurring is rare during the randomization.

3) The customers' location derived from random sampling with Hawth's tool that spread all over Bangkok metropolitan region may be misrepresented because they were distributed evenly. The research recommended developing the tools that could generate better representative. The idea to generate number of samples by the ratio of population density is suggested.

4) This research did not consider travel time as a factor for finding service levels. This is because the time data is highly dynamic according to speed on the road which essentially varies by time of day. Such data input the time is hard to estimate with precision. It is interesting to explore the possibility to utilize real time traffic data to compute the SLA on the road network as the Intelligent Transportation System (ITS) technology has become more popular.

5.4 Recommended Future Researches

It is expected that the following future research idea should be very interesting and provide useful results:

1) This research studied only gas stations located within the area of Bangkok metropolitan region. Further studies may attempt to perform analysis by expanding the study area to cover the whole country and separate results by regions. Thereby, the SLA by area may be specified.

2) Internet technology has been playing increasing roles in the daily lives. Some crucial information should be developed based on the internet technology. Thereby, the information on the road and locations of gas station may be obtained by web service such as Google Map etc. By doing so, the need for a license of ArcGIS is relieved since it is expensive. The internet-based system should be more effective and accrued lower cost.

3) The development of a computerized program that could be used to determine SLA is useful. This proposed concept in this research is readily available. Many businesses can be benefited from such developed program.

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APPENDICES

APPENDIX A
THE PROCEDURE FOR PREPARING THE SHAPEFILE OF BANGKOK METROPOLITAN REGION

1. Open ArcGIS then add Thailand spatial data as Admin_Province.shp.
2. Open Attribute Table to select province data area (See Figure A.1).

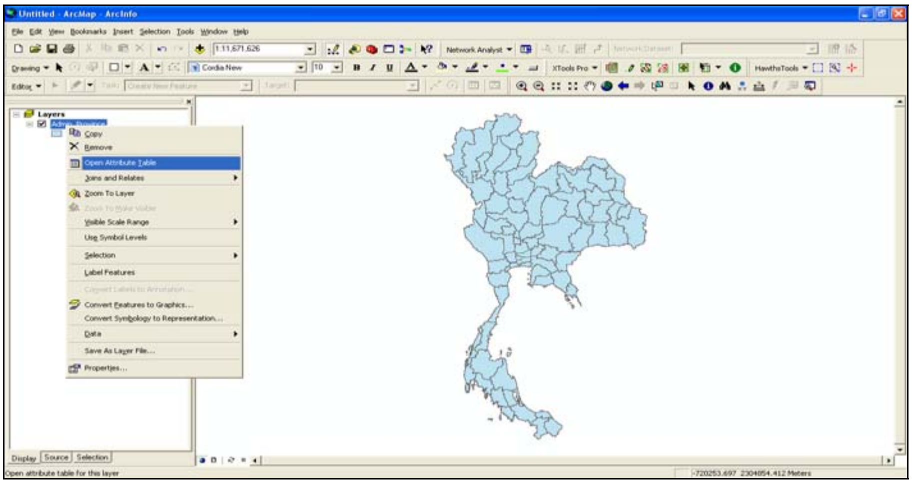
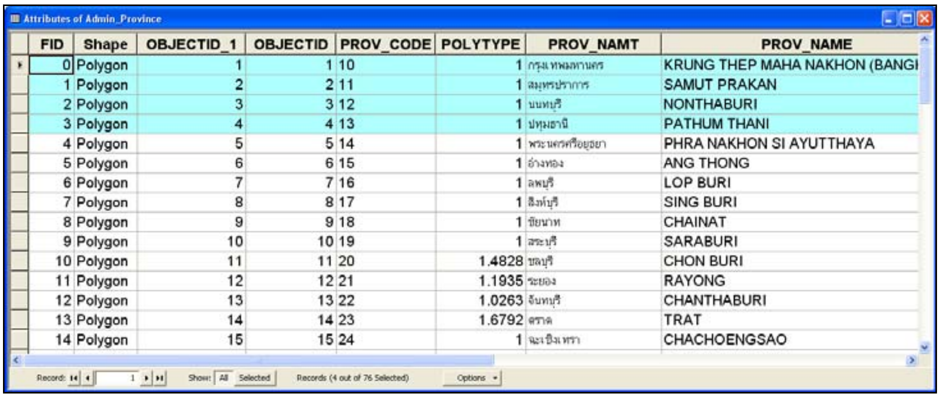


Figure A.1 Province data

3. Select Bangkok Nonthaburi, Pathumthani and Samutprakan Province data area.



Attributes of Admin_Province

FID	Shape	OBJECTID_1	OBJECTID	PROV_CODE	POLYTYPE	PROV_NAMT	PROV_NAME
0	Polygon	1	1	10	1	กรุงเทพมหานคร	KRUNG THEP MAHA NAKHON (BANGI
1	Polygon	2	2	11	1	สมุทรปราการ	SAMUT PRAKAN
2	Polygon	3	3	12	1	นนทบุรี	NONTHABURI
3	Polygon	4	4	13	1	ปทุมธานี	PATHUM THANI
4	Polygon	5	5	14	1	พระนครศรีอยุธยา	PHRA NAKHON SI AYUTTHAYA
5	Polygon	6	6	15	1	อ่างทอง	ANG THONG
6	Polygon	7	7	16	1	ลพบุรี	LOP BURI
7	Polygon	8	8	17	1	สิงห์บุรี	SING BURI
8	Polygon	9	9	18	1	ชัยนาท	CHAINAT
9	Polygon	10	10	19	1	สระบุรี	SARABURI
10	Polygon	11	11	20	1.4828	ชลบุรี	CHON BURI
11	Polygon	12	12	21	1.1935	ระยอง	RAYONG
12	Polygon	13	13	22	1.0263	จันทบุรี	CHANTHABURI
13	Polygon	14	14	23	1.6792	ตราด	TRAT
14	Polygon	15	15	24	1	ฉะเชิงเทรา	CHACHOENGSAO

Record: 1 Show: All Selected Records (4 out of 76 Selected) Options

Figure A.2 Province attribute table

4. Export Bangkok Nonthaburi, Pathumthani and Samutprakan Province data.

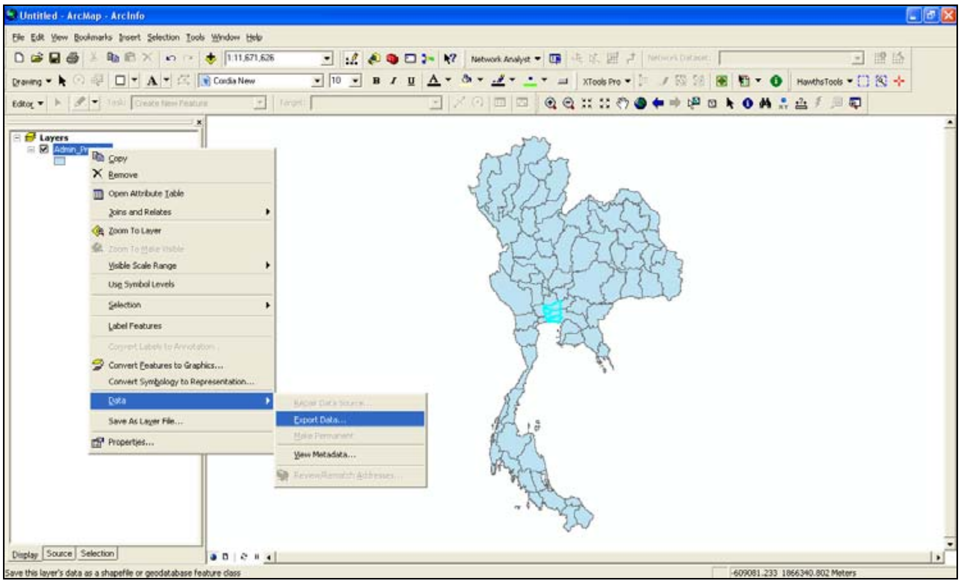


Figure A.3 Export province data

5. Save as Metro_Province.shp.

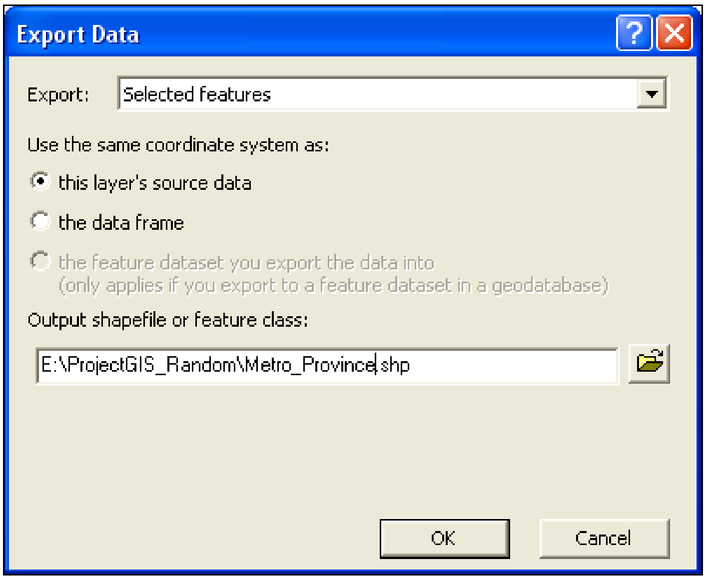


Figure A.4 to define output shapefile

6. After the selection the spatial data of Bangkok metropolitan region will be displayed.

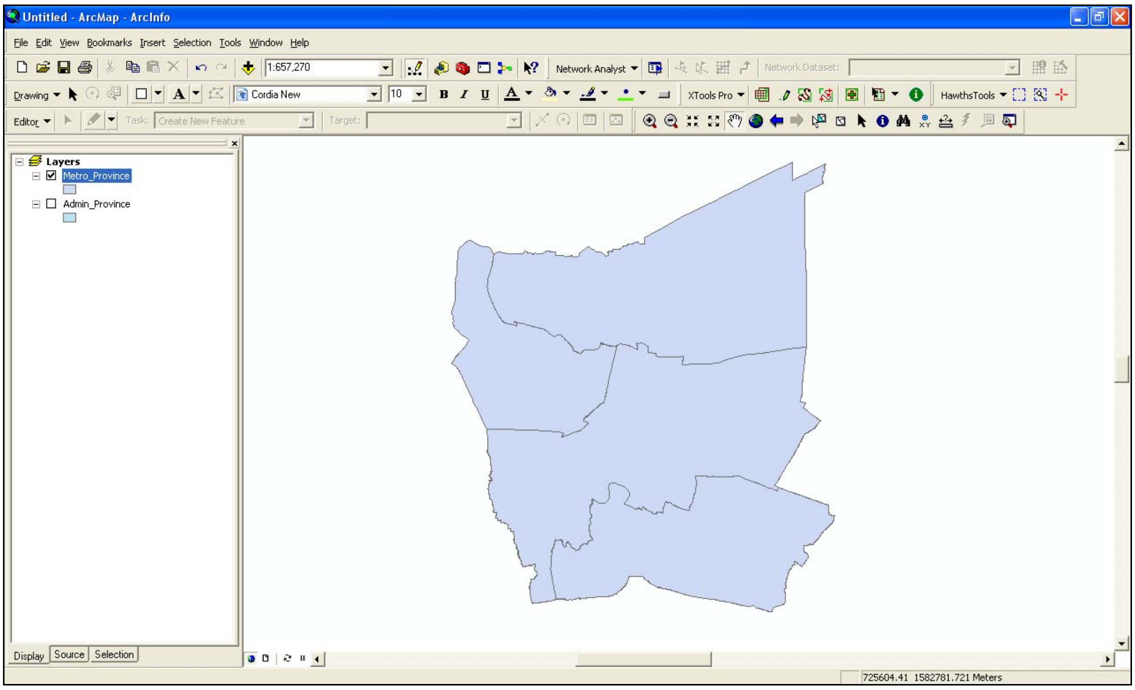


Figure A.5 Bangkok metropolitan region

APPENDIX B

THE PROCEDURE FOR PREPARING THE ROAD DATA SHAPEFILE IN BANGKOK METROPOLITAN REGION

1. Open ArcGIS then add data of Thailand roads as road.shp and Metro_Province.shp file.
2. Open ArcGIS to add road.shp and Metro_Province.shp which are the Thailand road data and Bangkok metropolitan region data.
3. Go to tab menu to choose Select by location function for select road data (See Figure B.1).

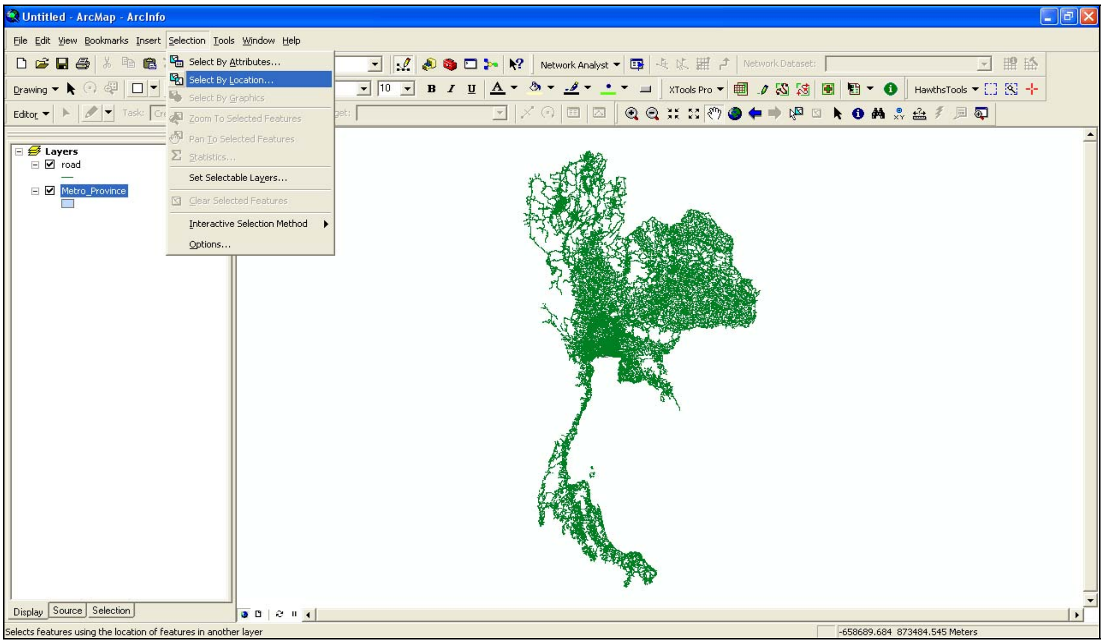


Figure B.1 Road network data in Thailand

4. Select data layer (road) to intersect with Bangkok metropolitan region data layer (Metro_Province) in order to get only data of these areas (See Figure B.2).

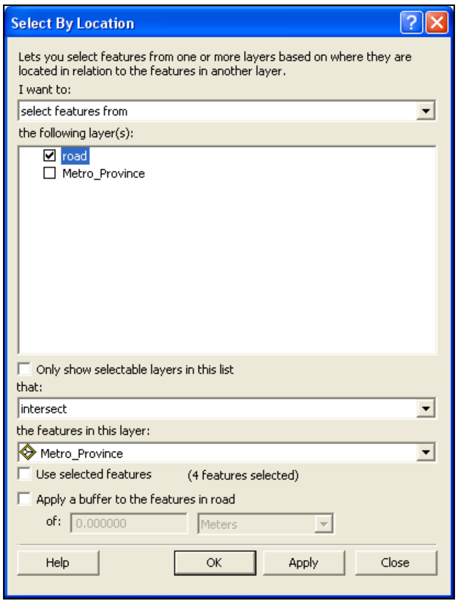


Figure B.2 Select road layer data to intersect with Bangkok metropolitan region

5. This tool will be used to display Bangkok metropolitan region data layer which has already been selected.
6. Export the road layer (See Figure B.3).

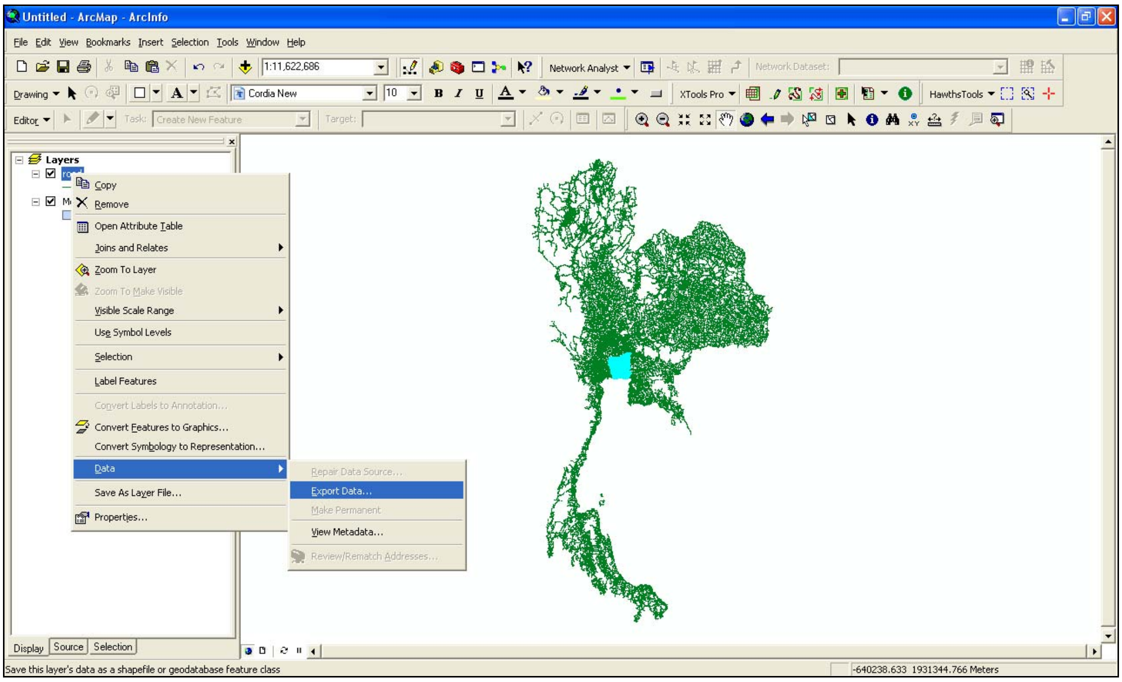


Figure B3 Road network in Bangkok metropolitan region

7. Save as Metro_Road.shp

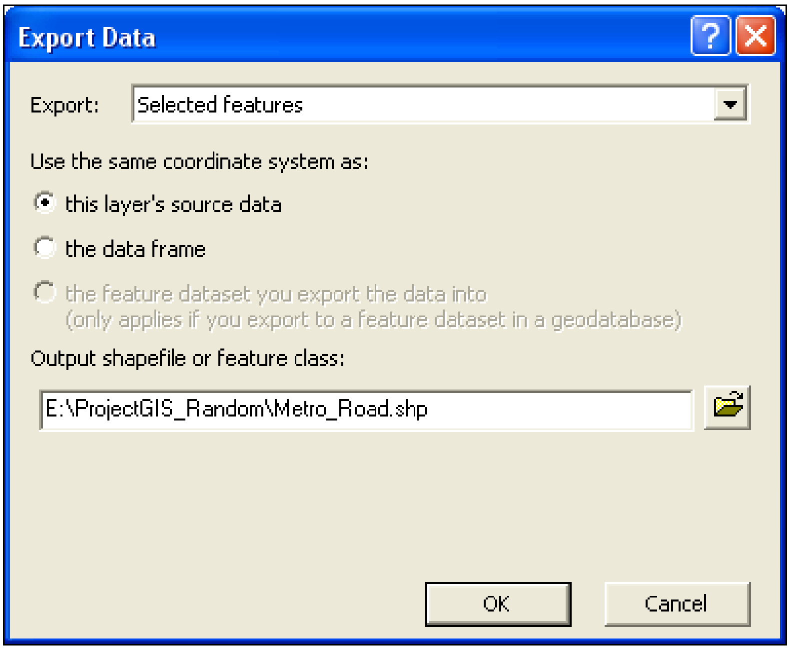


Figure B.4 to Define output shapefile

8. The road data shown in Bangkok metropolitan region output.

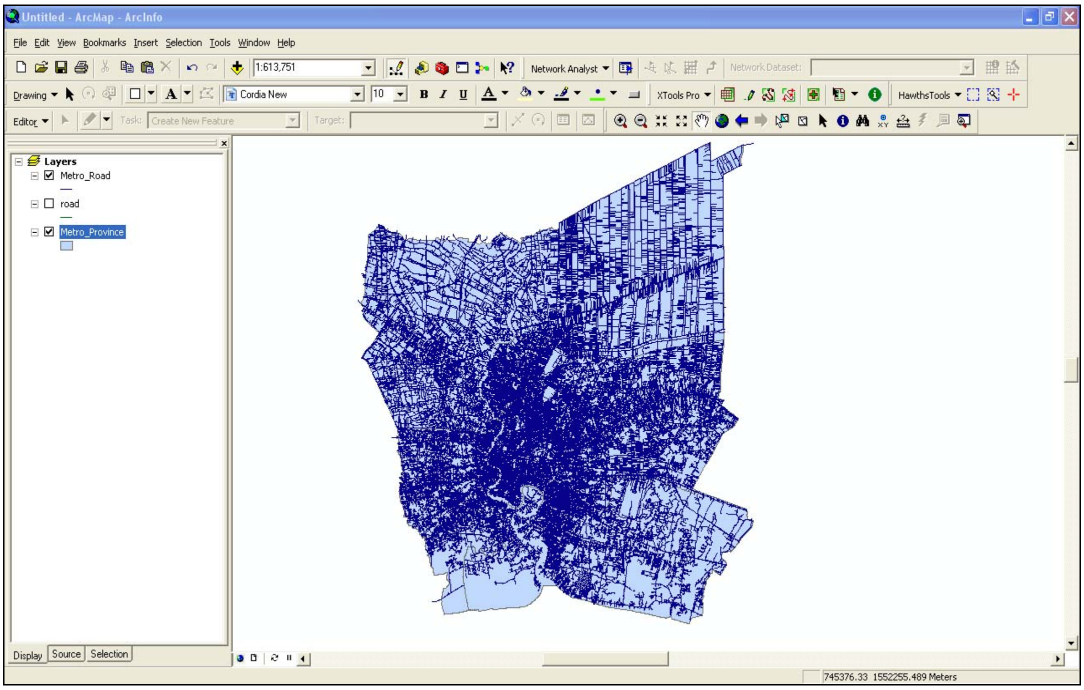


Figure B.5 Road network in Bangkok metropolitan region

APPENDIX C
THE PROCEDURE FOR PREPARING THE GAS STATION SHAPEFILE DATA IN BANGKOK METROPOLITAN REGION

1. Open ArcGIS, then add more data of landmark.shp file which include data of places in Thailand's location such as Hospital, School etc. and Metro_Province.shp file.
2. Open Attribute Table to landmark (See Figure C.1).

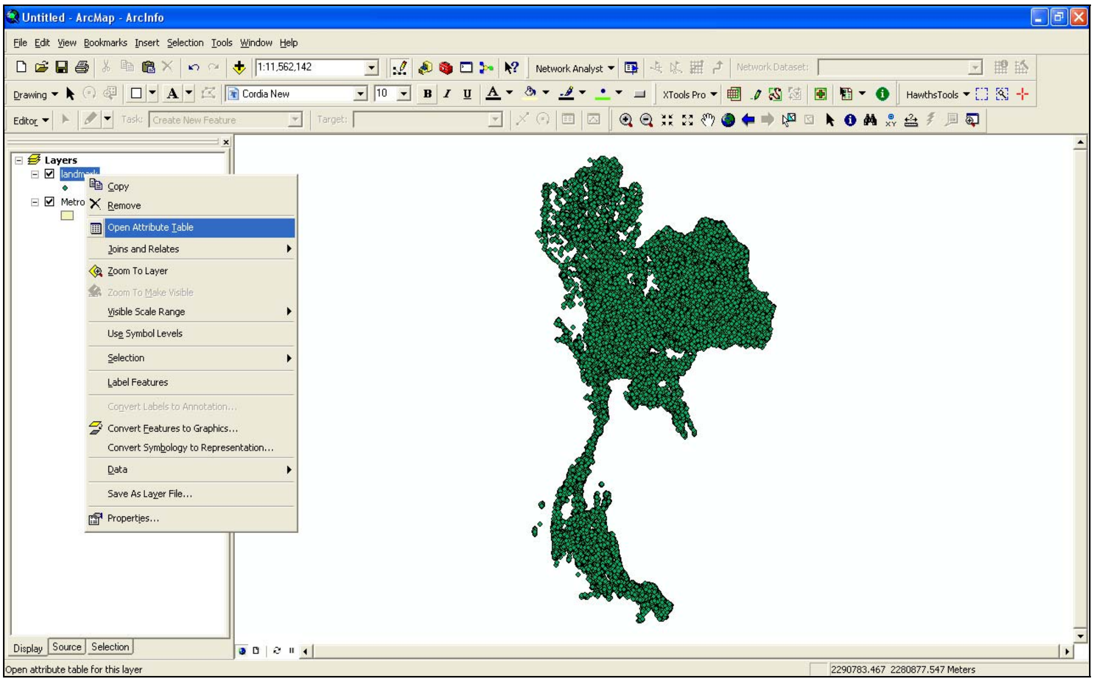


Figure C.1 Landmark layer data

3. Select Attributes in order to choose data on each attribute which needed.

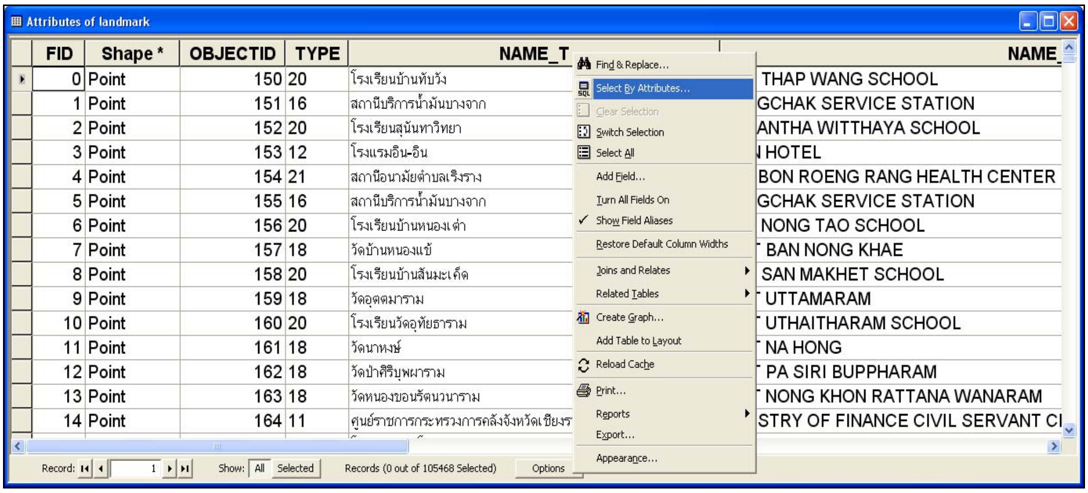


Figure C.2 Landmark attribute table

4. Use SQL command "NAME_E" LIKE '%SERVICE STATION' in order to select gas stations data (See Figure C.3).

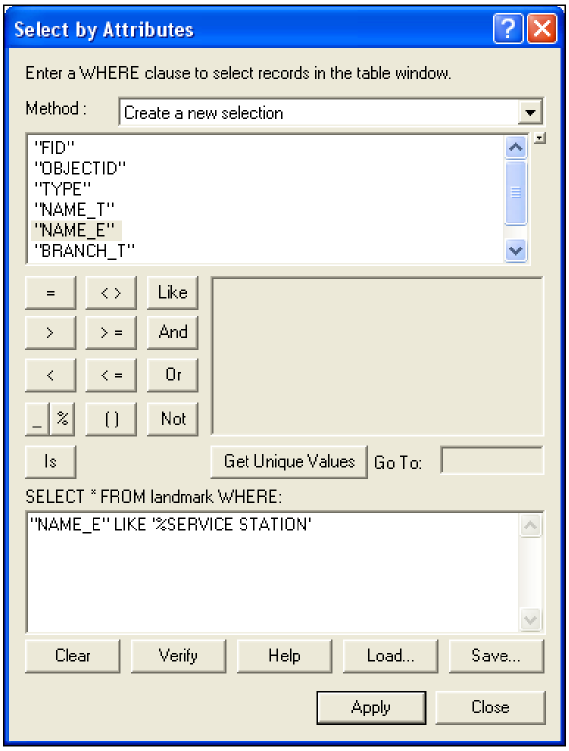
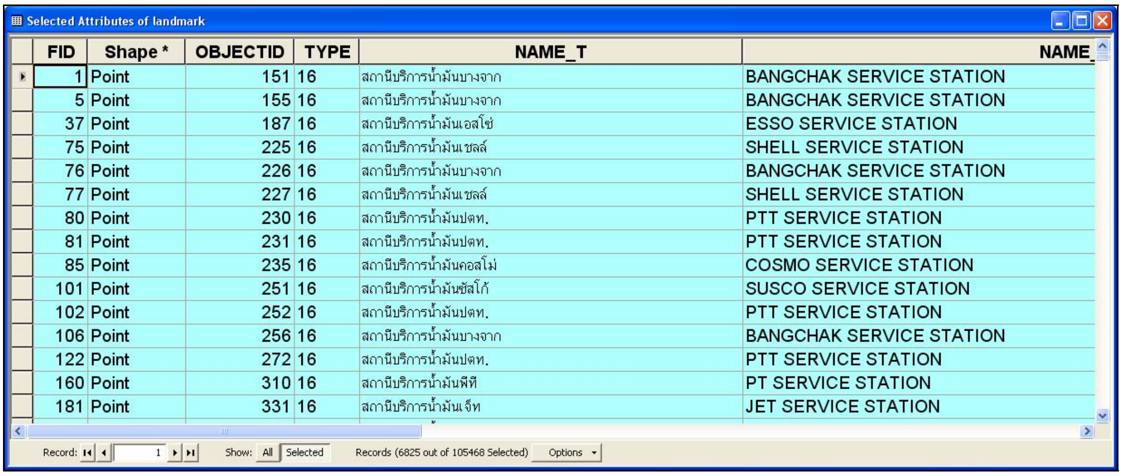


Figure C.3 Select gas station with SQL command

5. Program will select only Data of all gas stations data in Thailand as assigned.



Selected Attributes of landmark

FID	Shape *	OBJECTID	TYPE	NAME_T	NAME_
1	Point	151	16	สถานีบริการน้ำมันบางจาก	BANGCHAK SERVICE STATION
5	Point	155	16	สถานีบริการน้ำมันบางจาก	BANGCHAK SERVICE STATION
37	Point	187	16	สถานีบริการน้ำมันเอสโซ่	ESSO SERVICE STATION
75	Point	225	16	สถานีบริการน้ำมันเชลล์	SHELL SERVICE STATION
76	Point	226	16	สถานีบริการน้ำมันบางจาก	BANGCHAK SERVICE STATION
77	Point	227	16	สถานีบริการน้ำมันเชลล์	SHELL SERVICE STATION
80	Point	230	16	สถานีบริการน้ำมันปตท.	PTT SERVICE STATION
81	Point	231	16	สถานีบริการน้ำมันปตท.	PTT SERVICE STATION
85	Point	235	16	สถานีบริการน้ำมันคอสโม่	COSMO SERVICE STATION
101	Point	251	16	สถานีบริการน้ำมันซัสโก้	SUSCO SERVICE STATION
102	Point	252	16	สถานีบริการน้ำมันปตท.	PTT SERVICE STATION
106	Point	256	16	สถานีบริการน้ำมันบางจาก	BANGCHAK SERVICE STATION
122	Point	272	16	สถานีบริการน้ำมันปตท.	PTT SERVICE STATION
160	Point	310	16	สถานีบริการน้ำมันพีที	PT SERVICE STATION
181	Point	331	16	สถานีบริการน้ำมันเจ็ท	JET SERVICE STATION

Record: 1 Show: All Selected Records (6825 out of 105468 Selected) Options

Figure C.4 All gas stations data in Thailand

6. Export gas station data.

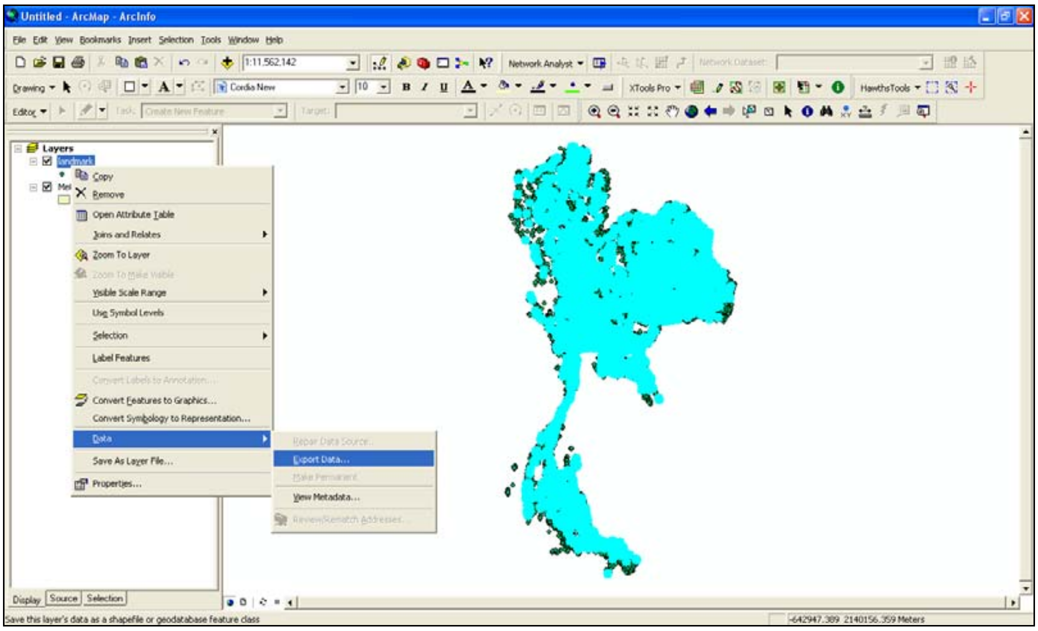


Figure C.5 Export gas station data

7. Save as All _Gas_Stations.shp.

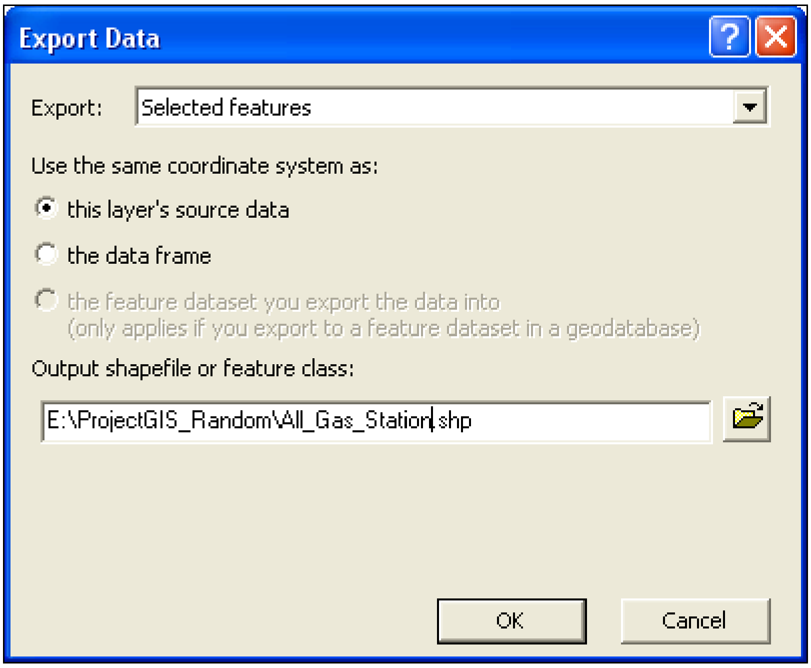


Figure C.6 to Define output shapefile

8. Select Location in order to choose data on each attribute which needed.

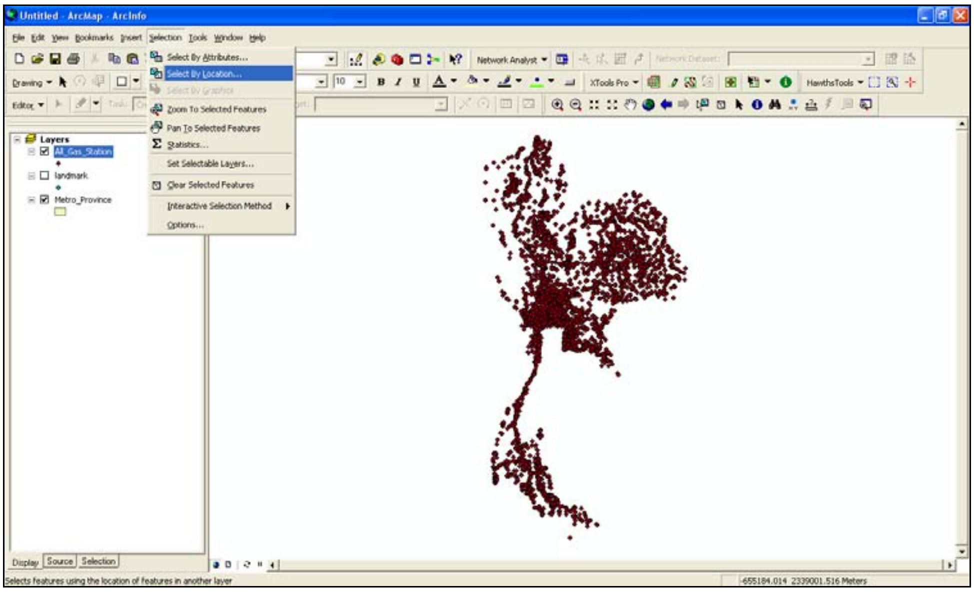


Figure C.7 Select by Location

9. Select gas stations data layer (All_Gas_Station) to intersect with Bangkok metropolitan region data layer (Metro_Province) in order to get only data of these areas.

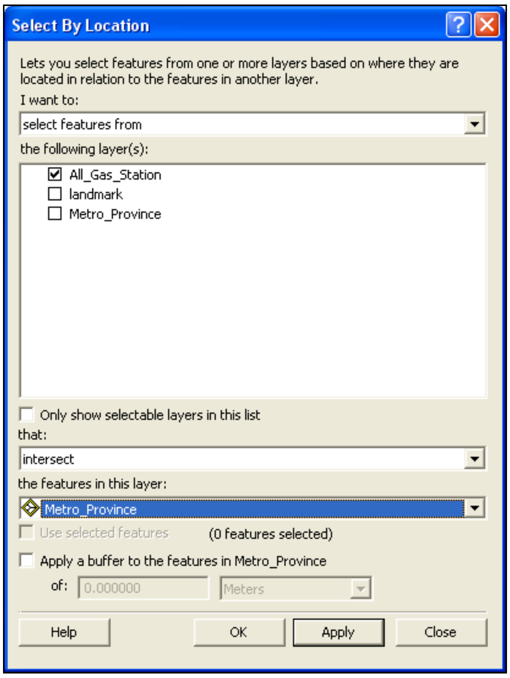


Figure C.8 Select gas station data layer to intersect with Bangkok metropolitan region

10. This tool will be used to display gas stations in Bangkok metropolitan region.
11. Export gas stations data.

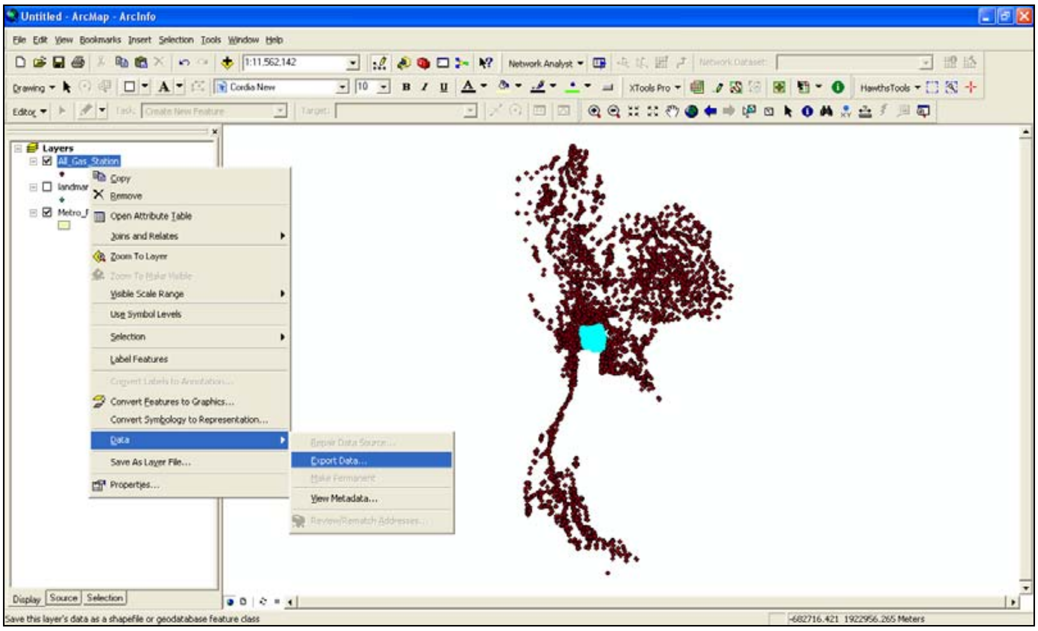


Figure C.9 Export data

12.Save as Metro_GasStation.shp.

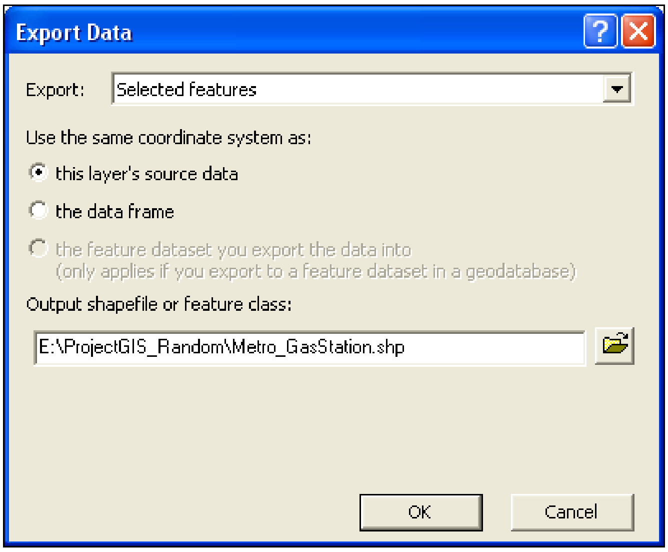


Figure C.10 to Define output shapefile

13.Gas stations data shown in Bangkok metropolitan region output.

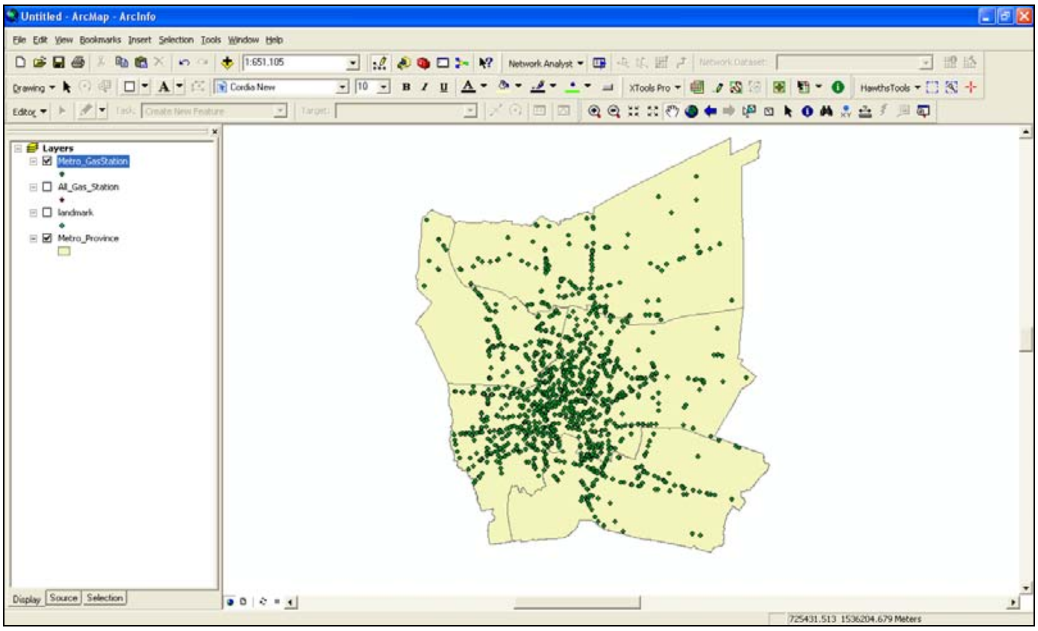


Figure C.11 Gas stations data in Bangkok metropolitan region

APPENDIX D

THE PROCEDURE FOR PREPARING ROAD NETWORK DATA FOR NETWORK ANALYST DATASET

1. Open ArcCatalog to setup road data layer.
2. Create Road Network by clicking on Network, select New and then select Network Dataset (See Figure D.1).

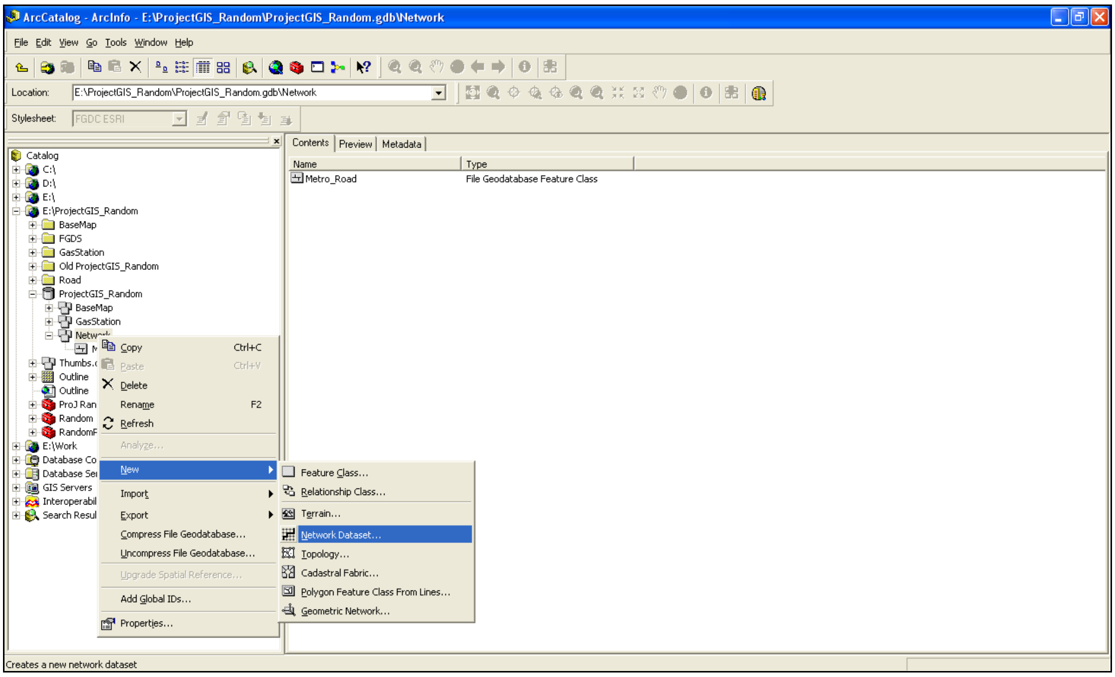


Figure D.1 Create new Network Dataset

3. Specify name of Network Dataset as Metro_Road_ND (See Figure D.2).
4. Click "Next"

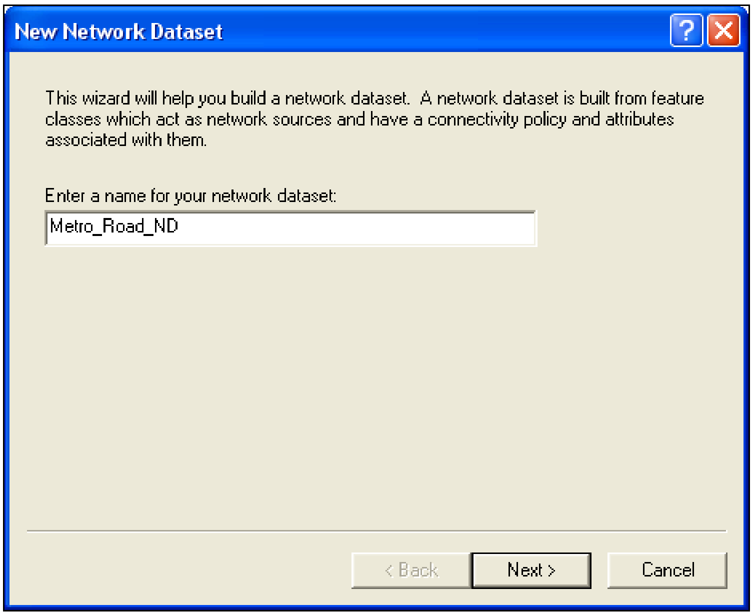


Figure D.2 New Network Dataset

5. Click "Next"

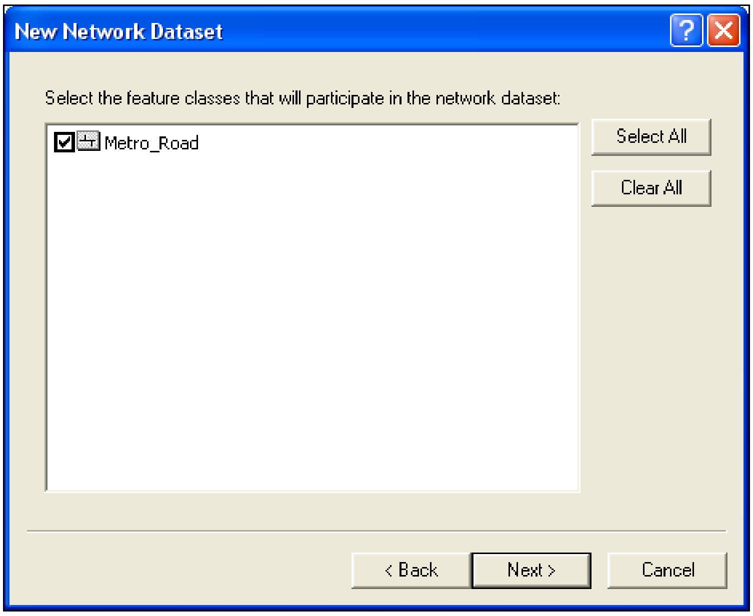


Figure D.3 Select the feature class

6. Select "No" because the research does not used road's height for the analysis data (See Figure D.4).

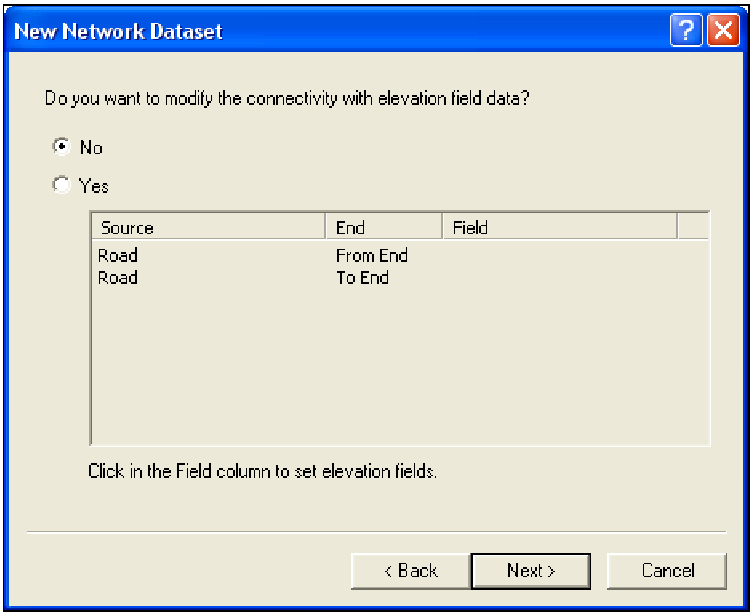


Figure D.4 Set elevation fields

7. Click "Yes"

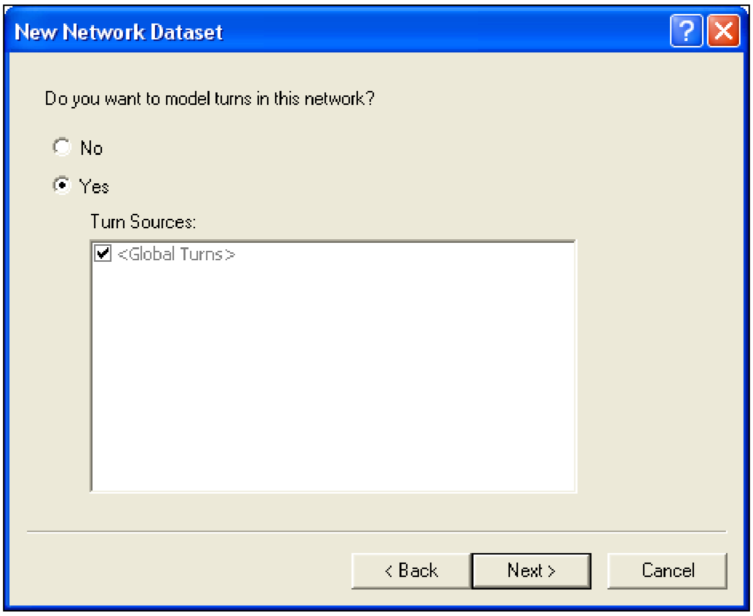


Figure D.5 Set turns sources

8. Specify Network Dataset's qualification by dividing into 4 categories as follows;

- Cost is the data that stipulates route's impedance. This research assigns only the distance to travel. Was used in meter unit. It is used to calculate the shortest path to travel.
- Descriptors are the data that stipulate route's qualifications such as Number of Road Lanes, Limit Speed on each road. However, this research does not use this information.
- Restrictions are the data that stipulate specify the routes such as one way lane, restriction of turnings etc. However, this research is focused on data of one way lane.
- Hierarchy is the data that stimulate classification of routes such as highway, main road and lane. However, this research does not use this information.

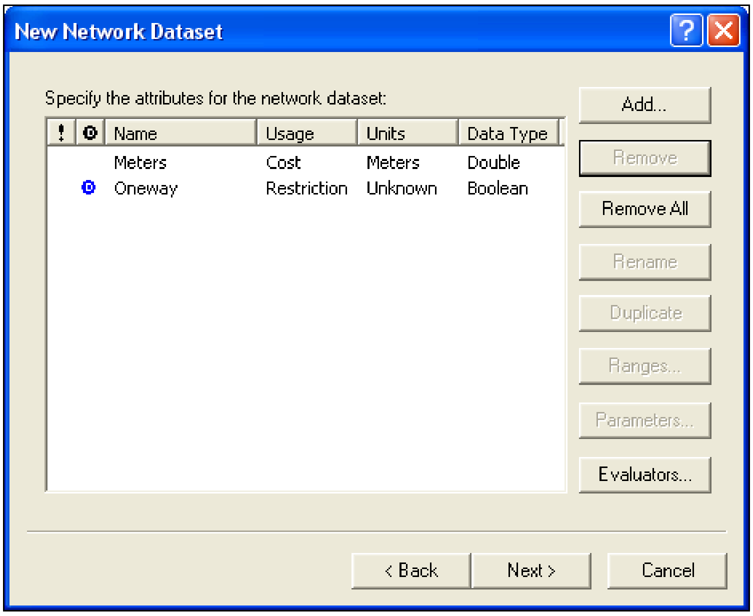


Figure D.6 Specify the attribute for the Network Dataset's properties

9. Designate direction of transportation driving by click on "Direction"

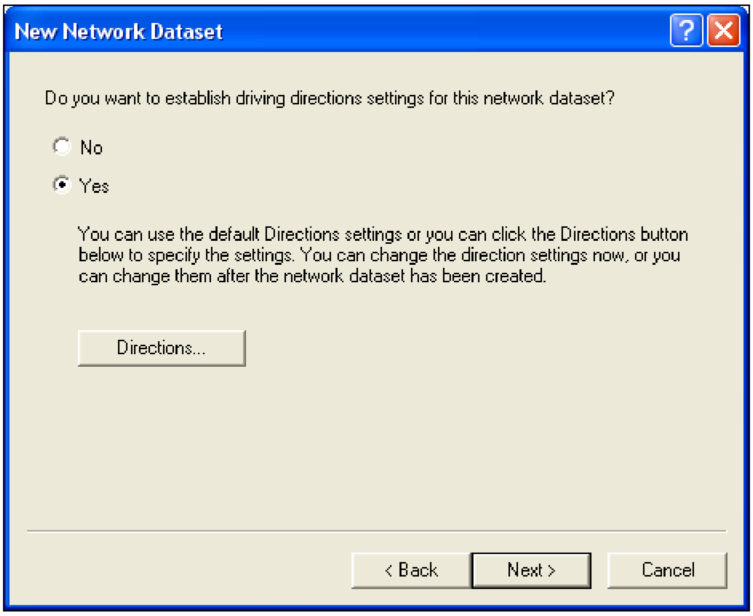


Figure D.7 to establish driving direction settings

10. Designate display unit as kilometer and display name of roads in English (See Figure D.8).

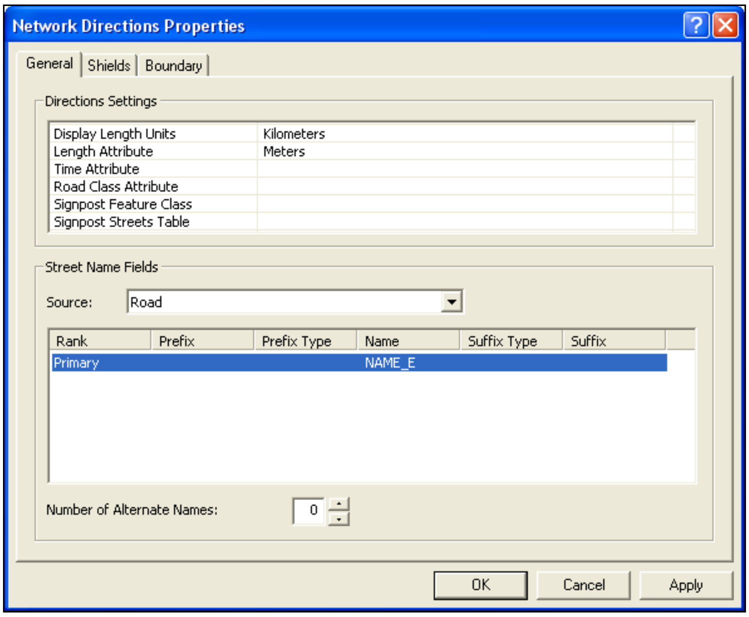


Figure D.8 Setting road name fields

11.When assigning value in Network Dataset finished. User can see the Network Dataset summary output. Click Finish to build the Network Dataset.

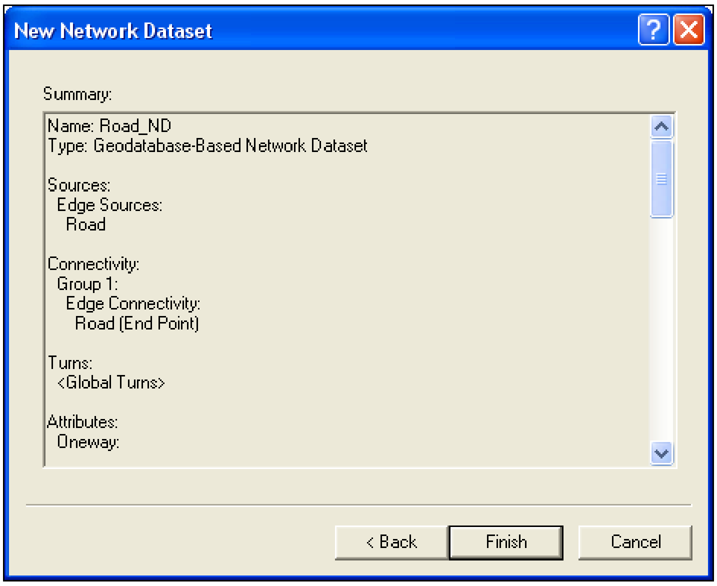


Figure D.9 Summary

12.Processing Network Dataset.

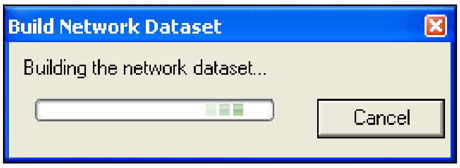


Figure D.10 Building the Network Dataset

13.Once finish creating Network Dataset, MetroRoad_ND file will be appeared as to be used for analyzing the routes.

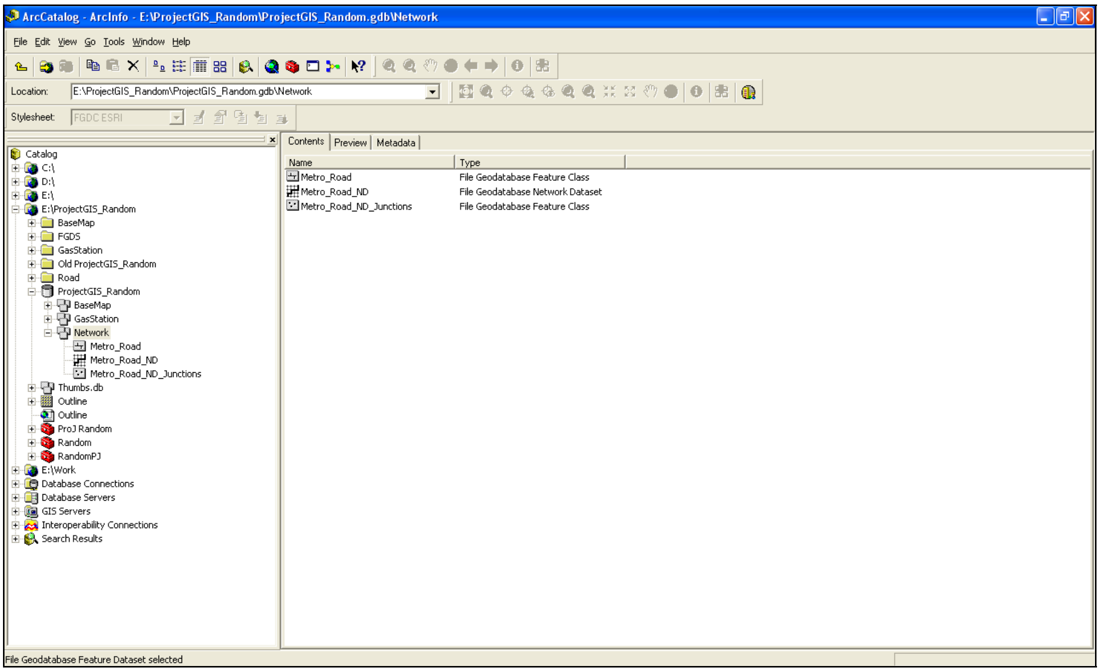


Figure D.11 Road Network Dataset in Bangkok metropolitan region

BIOGRAPHY

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