DECISION SUPPORT SYSTEM FOR THE PROCUREMENT OF MUNICIPAL SOLID WASTE COLLECTION TRUCKS: CASE STUDY IN BANGKOK

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DECISION SUPPORT SYSTEM FOR THE PROCUREMENT OF MUNICIPAL SOLID WASTE COLLECTION TRUCKS; CASE STUDY IN BANGKOK

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ABSTRACT

Developing a tool to plan the procurement of the collection trucks is the objective of this research. By using the Visual Basic Program, the necessary models, i.e. the estimation of municipal solid waste volume, the model for estimating numbers of collection trucks and the Linear Programming model, were engaged in the information system, which could store, update and process the collected data to collectively build up the Decision Support System for the Procurement of Municipal Solid Waste Collection Trucks. This decision support system presents an overview of a future plan for procuring the collection trucks and the relevant costs. Through analyzing the Linear Programming model, details of the optimal number of the collection trucks to purchase and/or rent on the basis of the minimal cost can be obtained.

The decision support system had processed all the inputs which comprised actual collection data and the other related factors and in turn presented the output in terms of the serial volumes of municipal solid waste in Bangkok of 10,412, 11,228, 12,033, 12,902 and 13,829 tons per day for the next five years respectively. In order to manage these wastes, the Bangkok Metropolitan Administration (BMA) is supposed to increase its collection truck fleet by 654, 160, 133, 246 and 312 units per year which will require its allocation of the annual budget of Baht 523,984,000, 128,983,800, 131,255,800 298,094,900 and 380,072,600 as its investment for the 1st to the 5th year respectively. The total collection cost of the additionally provided trucks for over the planning period is Baht 1,466,506,177.30.

KEY WORDS: DECISION SUPPORT SYSTEM/ COLLECTION TRUCK / LINEAR PROGRAMMING

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ระบบสนับสนุนการตัดสินใจเพื่อการจัดหารถเก็บขนมูลฝอย กรณีศึกษา: กรุงเทพมหานคร (DECISION SUPPORT SYSTEM FOR THE PROCUREMENT OF MUNICIPAL SOLID WASTE COLLECTION TRUCKS; CASE STUDY IN BANGKOK)

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บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อพัฒนาเครื่องมือที่ช่วยในการวางแผนจัดหารถเก็บขนมูลฝอย โดยการใช้โปรแกรม Visual Basic 6.0 ในการพัฒนาระบบสนับสนุนการตัดสินใจเพื่อการจัดหารถเก็บขนมูลฝอย ซึ่งได้มีการผนวกแบบจำลองคณิตศาสตร์ที่จำเป็น ได้แก่ แบบจำลองคาดการณ์ปริมาณมูลฝอย, แบบจำลองคาดการณ์จำนวนรถเก็บขนมูลฝอย และแบบจำลอง Linear Programming เข้ากับระบบสารสนเทศที่สามารถใช้ในการเก็บรวบรวม แก้ไข และประมวลผลข้อมูล ระบบสนับสนุนการตัดสินใจนี้สามารถให้ข้อมูลเบื้องต้นในการวางแผนจัดหารถเก็บขนมูลฝอยและค่าใช้จ่ายที่เกี่ยวข้องในภาพรวม และจากการวิเคราะห์ด้วยแบบจำลอง Linear Programming ระบบสามารถให้ข้อมูลจำนวนรถเก็บขนมูลฝอยที่ควรจัดซื้อและเช่า ซึ่งทำการวิเคราะห์บนพื้นฐานการเสียค่าใช้จ่ายเก็บขนมูลฝอยที่น้อยที่สุด

จากการประมวลผลของระบบสนับสนุนการตัดสินใจฯ โดยใช้ข้อมูลเก็บขนมูลฝอยและข้อมูลอื่นที่เกี่ยวข้อง ซึ่งผลการวิเคราะห์คาดการณ์ว่ากรุงเทพฯ จะเกิดมูลฝอยประมาณ 10,412, 11,228, 12,033, 12,902 และ 13,829 ตันต่อวัน ในปี 2548 – 2552 และกรุงเทพมหานครควรจัดหารถเก็บขนฯ เพิ่มประมาณ 654, 160, 133, 246 และ 312 คันในแต่ละปีตามลำดับ โดยต้องใช้งบประมาณในการจัดหารถประมาณ 523,984,000, 128,983,800, 131,255,800 298,094,900 และ 380,072,600 บาทในปีที่ 1 – 5 ตามลำดับ สำหรับค่าใช้จ่ายในการปฏิบัติงานเก็บขนมูลฝอยของรถที่จัดหาเพิ่มในช่วง 5 ปีของการวางแผนรวมเป็นเงิน 1,466,506,177.30 บาท

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CONTENTS

Page

ACKNOWLEDGEMENTS iii
ABSTRACT iv
LIST OF TABLES viii
LIST OF FIGURES x
CHAPTER

I INTRODUCTION 1
1.1 Background Justification 1
1.2 Objective 4
1.3 Scope of study 6
1.4 Expected Result 6
II LITERATURE REVIEW 8
2.1 Literature on solid waste management 8
2.2 Operation Research 20
2.3 Information System 24
2.4 Database system 31
2.5 Pertinent Research 35
III MATERIALS AND METHODS 37
3.1 Materials and Instrument 37
3.2 Data Resource 37
3.3 Method 38
3.4 Evaluation 47

CONTENTS (Continued)

Page

CHAPTER

IV RESULTS 49
4.1 Mathematic Model 49
4.2 System analysis and design 58
4.3 Analyzing optimal numbers of purchasing and renting collection truck of BMA 68
4.4 Evaluation 74
V CONCLUSION AND DISCUSSION 76
5.1 Solution to BMA's Waste Collection Problem 76
5.2 Efficiency of DSS for the Procurement MSW Collection Trucks 80
VI RECOMMENDATION 82
REFERENCES 84
APPENDIX 87
BIOGRAPHY 104

LIST OF TABLE

Table 1-2	Forecasting a daily average quantities of Bangkok' municipal waste generation since B.E. 2538 – 2558 by JICA versus an actual one of collection	5
Table 2-1	Typical solid waste generating facilities, activities, and locations associated with various source classifications	8
Table 2-2	Typical solid waste generating facilities, activities, and locations associated with various source classifications (continued)	9
Table 2-3	Comparison of solid waste generation in cities classified into three groups according to economic level.	10
Table 3-1	Municipal waste collection volumes per capita per day and GDP per capita of Bangkok since B.E. 2528 – 2539	41
Table 3-2	Municipal waste collection volumes per capita per day and GDP per capita of Bangkok since B.E. 2528 – 2539 (continued)	42
Table 4-1	An ANOVA table of running the SPSS program	51
Table 4-2	A Coefficients table of running the SPSS program	51
Table 4-3	Future volume of BMA's municipal waste was estimated by analysis program of DSS for the procurement of MSW collection trucks	69
Table 4-4	Numbers of required collection truck was estimated by analysis program of DSS for the procurement of MSW collection trucks.	70
Table 4-5	The output information about analyzing optimal numbers of purchasing and renting collection truck of BMA	71
Table 4-6	The output information about analyzing optimal numbers of purchasing and renting collection truck of BMA (continued)	72

LIST OF TABLE (Continued)

Table 4-7 The output information about analyzing optimal numbers of purchasing and renting collection truck of BMA (continued) 73

Table 4-8 The output information about analyzing optimal numbers of purchasing and renting collection truck of BMA (continued) 74

Table 4-9 The result of evaluation about the system efficiency and the user friendly of the DSS for the procurement of MSW collection trucks by 10 users 75

Table 5 – 1 Comparison of BMA's municipal waste estimations by JICA, DSS for the procurement of MSW collection trucks and JBIC 76

Table 5 – 2 The optimal number of collection truck to purchase and rent 78

Table 5 – 3 The total annual investment in and maintenance costs per unit per round of the purchased trucks and rented ones of the plan 79

Table 5 – 4 The total investment cost of the provided trucks 79

Table C – 1 Estimation of Thailand's economic trend in B.E. 2548 – 2552 100

Table C – 2 Data about time motion study of BMA's municipal waste collection 101

LIST OF FIGURES

Figure 1-1	Cost of solid waste collection since B.E. 2533 – 2542	4
Figure 1-2	Conceptual Framework	7
Figure 2-1	Conception framework of materials balance analysis	14
Figure 2-2	The components of an information system and their performance	25
Figure 2-3	The system development life cycle	26
Figure 2-4	The relationship among the three levels of abstraction.	32
Figure 2-5	Symbols of the E-R diagrams	34
Figure 3-1	Conceptual process of the decision support system for the procurement of MSW collection trucks's model	39
Figure 3-2	Trend of the change in population, GDP and waste quantity since B.E. 2528 – 2539	40
Figure 3-3	Methodology Chart	48
Figure 4-1	Context Diagram of Solid Waste Management System	59
Figure 4-2	Level 0 Data Flow Diagram of Solid Waste Management System	60
Figure 4-3	Level 1 Data Flow Diagram of Solid Waste Management System	61
Figure 4-4	ER-Diagram of Solid Waste Management Database	62
Figure 4-5	Dialogue diagram for the DSS for the procurement of MSW collection trucks.	64
Figure 4-6	Top-Level Structure chart of DSS for the procurement of MSW collection trucks.	65
Figure 4-7	Structure chart for Viewing the District Information section of system	66
Figure 4-8	Structure chart for Viewing the Collection Information section of system	66
Figure 4-9	Structure chart for Analyzing the Estimated waste Volume Waste of system	67

LIST OF FIGURES (Continued)

Figure 4-10	Structure chart for Analyzing the Collection Truck Procurement by Linear Programming method of system.	68
Figure A – 1	Main form of DSS for the procurement of MSW collection trucks	88
Figure A – 2	Zone Database form of DSS for the procurement of MSW collection trucks	88
Figure A – 3	Waste Collection Database form of DSS for the procurement of MSW collection trucks	89
Figure A – 4	Waste Volume Estimation form of DSS for the procurement of MSW collection trucks	89
Figure A – 5	Collection Truck Number Estimation form of DSS for the procurement of MSW collection trucks	90
Figure A – 6	Linear Programming Analysis form of DSS for the procurement of MSW collection trucks	90
Figure A – 7	Solution form of DSS for the procurement of MSW collection trucks	91
Figure A – 8	Help form of DSS for the procurement of MSW collection trucks	91

CHAPTER I
INTRODUCTION

1.1 Background Justification

Solid wastes are those remainders to be deserted and undesired from human activities, so they are hugely generated in a city where a center of business and industry is. The more the city has been developed, the more the hugely solid waste problem it will be faced. Solid waste problem always appear in obvious view through a heap of garbage scene. This problem affects not only sanitary aspect of the people but also the well panorama as well as the other pollution issues, such as odor, leachate, to the environment.

Beforetime, handling of solid waste was easily depended on the natural decomposition. The waste was neither a large amount nor a complex composition. Therefore, open dumping was generally an acceptable method to be adopted in various regions. Today, the waste is generated in a huge amount of quantity and in a multifarious composition, whereas, the natural decomposition is a limited capacity. As a result, it is extreme to handle by the former method. The waste composition is also composed of various compounds, especially hazardous compound, which cannot be decomposed by the natural process and will accumulate in the environment. Consequently, open dumping is no longer an acceptable method for dispose of waste as it is proved to arise risk and harm to the environment, such as groundwater, soil, etc; and peoples who exist in its. Although presently, there are a lot of new technologies that well developed and have been adopted to solve a waste disposal problem as well as to protect the environment. However, due to their sophisticate and extreme cost, they drawback some regions in employing them in practice. On the other hand, increasing of waste quantity results in more and more problematic waste collection. The wastes are daily generated in a large amount in the commercial and dense populated areas that have got to be finished its collection. Besides, the dense and location of constructions, inconvenience road conditions and traffic congested with in the Bangkok Metropolitan areas forming the complicated routes which lead to the time consuming and high operation cost for the collection.

As all above mention identified that the main problem of the solid waste management arose from the developing and centralizing of business and industry in the city that encourage the change in quantity and composition of wastes. This problem results in the complicated and difficult for waste collection and disposal, consequently, numerous resources are used to cope with it. Currently, solid wastes about 9,000 tons are generated daily in the Bangkok city. This amount of waste is discharged and placed for proper handling by the Bangkok Metropolitan Administration (BMA) as a local government. Wastes were collected and transported to the transfer station by the responsibility of 50 district offices of BMA and transfer to dispose by sanitary landfill at the private landfill sites. Although, presently BMA can address those waste, but according to the Solid Waste Management Master Plan studied by JICA in B.E. 2534 it may generated more than 15,000 tons per day of waste for next 10 years. In that case, it will be hardly managed with the limited resource of BMA, especially, waste collection, which consumes the most budget for solid waste management. To confront with the huge amount of waste in future, BMA has provided a numerous of both manpower and equipments that implies to increase a great number of budget. In B.E.2543, BMA used their budget about 1,535 million bath or around 75% of the total solid waste management budget for waste collection. (1) Furthermore, according to the report on the BMA' solid waste collection cost since B.E. 2533 illustrates their trend increased year after year. (2) One of the solid waste collection problems is the utilization of the old collection trucks which most of which using over seven years. This brings about not only the high fuel consumption and high maintenance cost but also rapid depreciation of the trucks. BMA realized this situation and required to replace all those trucks, however, due to the restricted budgets this desire has not accessible. An alternative of solution, which BMA chosen, is to rent the private trucks for replacing the depletion ones. Nevertheless, this concept is considered high capital cost compare with the purchasing. In order to maximize the efficiency for the management and economy as possible, it is worthwhile to analyze an appropriate number for the collection trucks providing by purchasing and renting. Encounter, the planning for waste collection should be considered on an overview so that the plan on solid waste management being able to deal with a large amount of waste generated efficiently.

Such planning needs to exploit various data that are processed as to formulate the useful information and then analyze them in systematically to illustrate alternative solutions. The optimal one will be decided on for the implementation. Using an information system, all related data will be able to process conveniently by means of input, delete, update and generate the rapid and accuracy information for supporting the management decision. While planning on the future term, whether short or long term plan, several of related information would be analyzed to predict and estimate the magnitude of problems as well as to find out the effective solution to tackle them. This can be achieved by technique of Operation Research (OR) that is a management science or an approach to managerial decision-making, which is based on science method. (3) Therefore, decision support system for plan out the providing of collection trucks by purchase and rent will be able to established by integrating OR technique into computer-based information system to present preliminary information for the acquaints administrators. The results from the system demonstrate the optimum alternative for providing the trucks through cost assessment, which is beneficial for the decision-making in planning for waste collection on overview.

1.2 Objective

To develop the Decision Support System for the Procurement of Municipal Solid Waste Collection Trucks (DSS for the procurement of MSW collection trucks) that can provide the information about the forecasting amount of waste to be generated, the required collection trucks and cost for handling the collection system. By employing the methodology of Operation Research, all relevant information will be decided to perform the vital output for supporting the decision making on planning for the procurement of the MSW collection trucks by purchasing and renting and also providing the preliminary information for waste collection cost on overview.

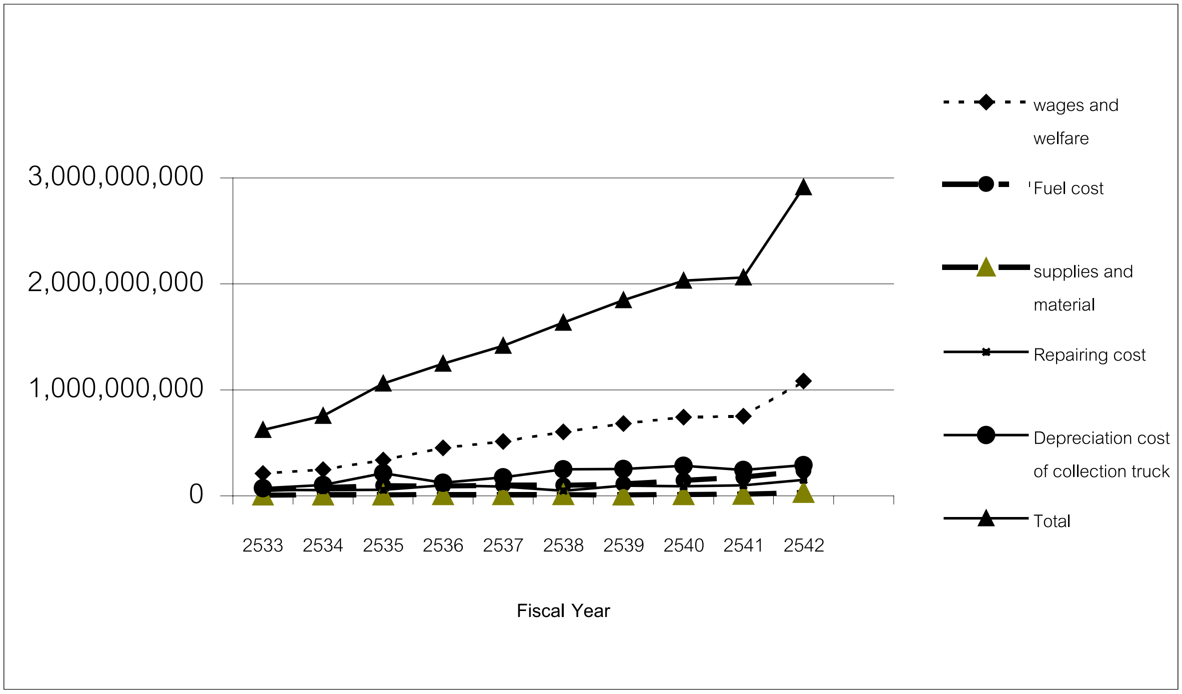

Figure 1-1 Cost of solid waste collection since B.E. 2533 – 2542

Source Department of Public Clearing Report 2543

1.3 Scope of study

1.3.1 Users, who are target group of this study, are the officers in charge of the Department of Public Cleaning, BMA, whose requirement will be integrated into information system.

1.3.2 The solid waste management system of BMA, which focus on Research and Planning Division, is study area of information system' scope

1.3.3 To study a waste collection projects, policy and solid waste management plan in order to identify problem, objective and constraint as well as apply Operation Research technique to find out their solution.

1.3.4 To study information system development that has feature follow this;

- To store related data of solid waste management and process it, i.e. input, delete and update, as well as report its information.
- To predict and estimate quantity of generated waste, including adequate numbers of truck to deal it.
- To inform an optimal numbers of purchase and rental truck and their expenditure to support decision making on planning for waste collection.

Table 1-2 Forecasting a daily average quantities of Bangkok' municipal solid waste generation since B.E. 2538 – 2558 by JICA (2).

Year	Daily Quantity of Municipal Waste (Ton)			
	An Estimated Quantity of future waste	A Collection Quantity of waste	Increasing of Waste Quantity	
			Ton per Day	Percent
2538	7,020	6,633.71	-	-
2539	7,540	8,000.86	1367.15	20.61
2540	8,070	8,703.25	702.39	8.78
2541	8,630	8,591.72	-111.53	-1.28
2542	9,210			
2543	9,800			
2544	10,410			
2545	11,030			
2546	11,650			
2547	12,280			
2548	12,920			
2549	13,550			
2550	14,180			
2551	14,800			
2552	15,420			
2553	16,020			
2554	16,600			
2555	17,170			
2556	17,720			
2557	18,250			
2558	18,750			

1.4 Expected Result

1.4.1 A proper information system that can input, process and output data or information of solid waste management as well as elaborate on assessment of collection cost and the number of collection truck to be purchased and rented in order to support decision making on the planning of waste collection.

1.4.2 A user-friendly program on Decision Support System for the procurement of the MSW collection trucks to be used for BMA and to be adopted by other local authorities.

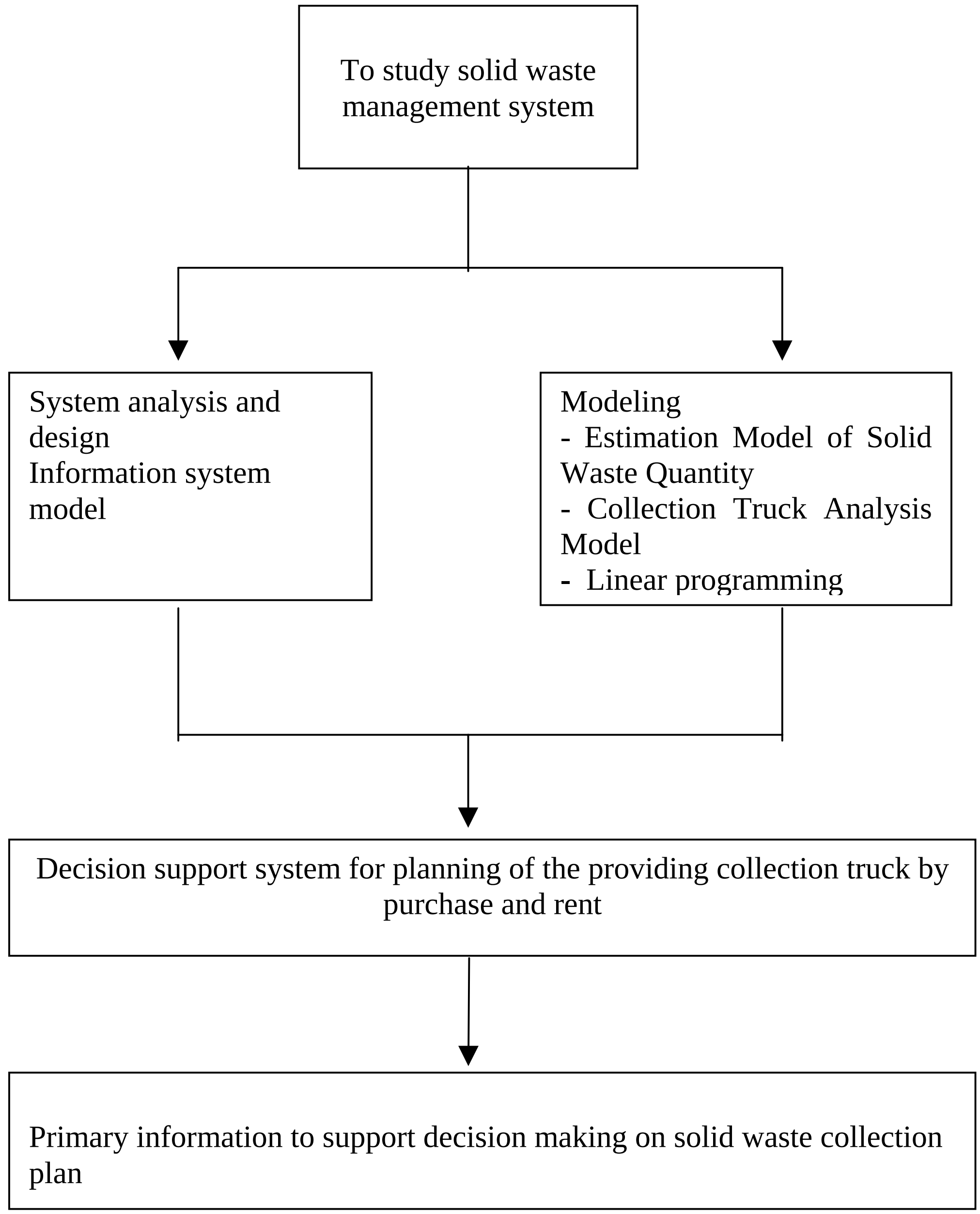

Figure 1-2 Conceptual Framework

CHAPTER II
LITERATURE REVIEW

2.1 Literature on solid waste management

2.1.1 Generation of solid waste

There are some issues relate to the generation of solid waste that should be reviewed. Its detail is as follows this:

2.1.1.1 Sources and types of solid waste (5)

Sources of solid wastes are generally related to land use and zoning, such as residential, commercial, industrial area and so on, accordingly, types of wastes are associated with activities of these sources. Classifications of sources and their facilities, activities, or locations that waste was generated are presented in Table 2-1 of which municipal waste will be focus in this research.

Table 2-1 Typical solid waste generating facilities, activities, and locations associated with various source classifications

Source	Typical facilities, activities, or location	Type of solid waste
Residential	Single and multi-family dwellings, low, medium, and high rise apartments, etc.	Food wastes, rubbish, ashes, special wastes
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, auto repair shops, medical facilities and institutions, etc.	Food wastes, rubbish, ashes, demolition and construction wastes, special wastes, and occasional hazardous wastes.

Table 2-2 Typical solid waste generating facilities, activities, and locations associated with various source classifications (continued)

Source	**Typical facilities, activities, or location**	**Type of solid waste**
Municipal	As above, including both the residential and commercial solid waste generated in the community.	As above
Open areas	Streets, alleys, parks, vacant lots, playgrounds, beaches, highways, recreational areas, etc.	Special wastes, rubbish
Treatment plant sites	Water, waste water, and industrial treatment processes, etc.	Treatment plant wastes, principally composed of residual sludges
Agricultural	Field and row crops, orchards, vineyards, dairies, feedlots, farms, etc.	Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes

Source: Gerge Tchobanoglous, Hilary Theisen and Role Eliassen, Solid Waste: engineering principles and management issues, 1977.

2.1.1.2 Factor that affect solid waste generation

Generation of solid waste can be expected to depend on each of the following aspects:

(1) Physical Geographic factors

Certainly, the influence of geographic location is related to the different climate and season that affect quantity and characteristic of waste. Inter-area the warmer southern areas where the growing season is considerably longer than in the northern one, yard wastes are collected not only in greater amounts but also over a longer period of time. While, intra-area the quantities of certain types of solid waste are also affected by the season of the year (8), such as the quantities of food waste related to the growing season for vegetable and fruits. (8)

(2) Economical Factor

Solid waste is a refuse of human' activity, so economic factors, which connected with commercial, service and industrial activities, have certainly effect on waste generation. The economic variables that is generally used to indicate the relationship between economic growth and the generation rate of solid waste are following this:

- The gross domestic product (GDP) is the total value of all goods and services produces in a country that is economically used to measure developmental level of commercial and industrial activities in country. The relationship between increases in the GDP and the solid waste generation is roughly shown in Table 2-2; which illustrates a clear increase in waste generation with the advance of economic development.

Table 2-3 Comparison of solid waste generation in cities classified into three groups according to economic level.

	Group A	**Group B**	**Group C**
City	Dhaka, Kathmandu, Ulaanbaatar, Bhopal, Yangon	Cebu, Nonthaburi, Chongqing, Surabaya	Fukuoka, Kitakyushu, Macao
GDP (USD)	1,000 to 3,000	3,000 to 10,000	Over 10,000
Waste generation (Kg/person/day)	0.3 to 0.6	0.7 to 1.1	1.4 to 1.5

Source: United Nation Environment Programme, Newsletter and Technical Publicatio (Municipal Solid Waste Management)**;**Regional Overviews and Information Sources Asia

- Income: Because consumption of goods and service increases with income, so, there is reason to expect that at higher income generating more refuse. The Environmental Protection Agency (EPA) has studied factors affecting the generation of residential refuse and the demand for collection services. Base on some of the data gathered for the EPA study, Peter Kemper and John M.Quigley reanalyzed them to get some general insight into the relationship between economic variables and the demand for collection services by households. Their analysis suggested that higher income households generate more solid waste per capita than lower income households. (10)

(3) Demographic Factor

Human is the important subject to directly produce waste into environment. Certainly, the changing demographic trend must have made impact on generation rate of solid waste. This factor is always used as variable to evaluate the generation and the demand for collection of solid waste. In overview, the growing rate of population is the significant variable to correlate with the rate of developing economy and generating waste. For household waste generation can be expected to be responsive to variation in household size, with larger households generation more refuse than smaller households. Additionally, consumption patterns also vary with age and with other demographic characteristics.

(4) Other Factor

In addition to those factors affecting the variation in the waste generation, there are the other, such as public attitudes, legislation, source reduction, and so on, also have significantly effect on the quantities generated.

2.1.1.3 Quantities of Generated Solid Waste

In addition to knowing the source and type of the solid waste that must be managed, it is equally important to be able to estimate the amount of solid waste generated in practical area. Because many of the decision-making on solid waste management systems depend upon this information, for example, decision about the appropriate technology and size of the disposal facility as well as about the efficient design of collection system to deal with those wastes daily generated.

As for the way of assessing the amount of solid waste, Sutin Usue distinguishes the two following approaches:

(1) Load-count analysis: this approach at facility site, such as landfill site, transfer station or treatment facilities, the number of individual loads and the corresponding vehicle characteristics are noted over a specified time period. If scales are available, weight data are also recorded. These data are used to find out amount of waste quantities in weight are accounted by the following expression

$$W_t = {}^{100\,(W_c)}\!/_{n}$$

Where W_t = the weight amount of solid waste generated in local area over a specified time period

W_n = the weight amount of solid waste was collected in local area over a specified time period

n = proportion of a covered area of collection system to a whole local area

In practice, the end point of waste collected, such as transfer station, land fill site, and facilities, will be generally record such available data. So, this method is a convenient and economizes approach that will be used in this research. However, the most reported data describe the collected rather than the generated quantity as well as it is impossible to separate the source from which the wastes were derived. (5)

(2) Site-specific studies: surveying individual source, for example, dwelling, restaurant, market, etc., are used in order to sample and weigh the wastes generated as well as the related variables are noted over a time period of study. A generation rate of each source carries out by equation that is developed by linear regression and the total solid waste then is determined by following this equations: (6)

$$W = \sum_{i=1} W_i$$

And $$W_i = m_i \times p_i$$

Where W = Total quantity of waste generation (weight/time)

W_i = Quantity of waste generation at each source (weight/time)

m_i = Waste generation rate at each source (weight/time)

p_i = Amount of generation sources (source)

This approach is useful in defining a local waste quantities and characteristic, as well as inform on the particularly type of waste which is specially managed, such as infection waste, industrial waste. However, a disadvantage of sampling studies based on a limited number of samples is that they may be skewed and misleading due to errors in the sampling methodology. Any errors of this kind will be greatly magnified when a limited number of samples are taken to represent an entire waste stream of region or nation for a year. Also, extensive sampling would be prohibitively expensive for making their estimates. An additional disadvantage of sampling studies is that they do not provide information about trends unless performed in a consistent manner over a long period of time.

(3) Materials Mass Balance Analysis: Besides the two before approaches, the other one to be used in estimation of waste quantity is Materials Mass Balance Analysis to determine the generation and movement of solid waste by identifying all the activities that occur within study area and affect the generation of wastes.

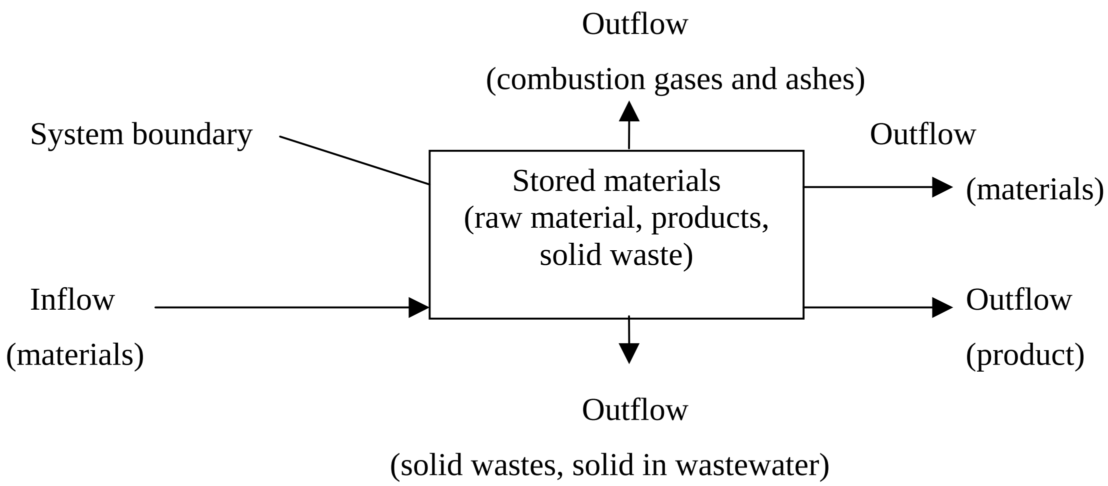

Figure 2-1 Conception framework of materials balance analysis (Gerge Tchobanoglous, Hilary Theisen and Samuel Vigil, 1993)

In Practice, the most difficult aspect of applying a mass balance analysis for the determination of waste quantities is defining adequately all of the inputs and output crossing the system boundary. (7)

From those methods, the first one, load-count analysis, will be used in this research. Since BMA has recorded waste quantity data discharged in transfer station that has usually been used for planning solid waste management.

2.1.2 Solid Waste Collection System

Alternative of collection system falls generally into three methods as follows. (7,12)

(1) Door-to-door system: this method is appropriately used to collect a discharged solid waste from small-volume generation, such as household, restaurants, store etc. In the door-to-door system, collection worker will visit every generation and collect the waste.

(2) Stationary system: same as former method, the small-volume generation is proper serviced by this. Differently from the former one, dischargers will bring their waste filled containers up to specified station on the specified day and

bring back their empty containers home after the collection service load content of the containers into collection trucks.

(3) Hauled container system: this method should be used to service a large-volume generation, such as a large markets, factories and so on. The hauled container system in composed of a container loader and some large containers, one of which is on the loader and the other located at generation sites. The full container of generator, which is filled with waste, will be loaded and replaced by the empty container. The container loader then hauls the full container to destination and empties it.

2.1.3 Solid Waste Collection Plan

The planning of solid waste collection system, the following issues are considered as regard the plan:

2.1.3.1 Future Solid Waste Quantity

Future quantities of solid waste are necessarily information used to plan for collection and disposal management. In practically, the difficulty in projecting future quantities is an uncertainty of variation and a variety of factors, which influenced generation of solid waste. So there is some way of solid waste' quantity projection from other researches as follows:

From the solid waste management guideline for the city and the regional metropolis by Health Science Major, Sukhothaitummatirart University, this research regarded the quantitative variation of waste generation to correlate a changing of population and a changing of economic indices, such as GDP (Gross Domestic Products) or GPP (Gross Provincial Products). The quantitative projection of solid waste generation is the following stages:

- To evaluate present rate of per capita solid waste generation.
- To forecast future population
- To estimate future rate of per capita solid waste generation, which base on the present rate of per capita solid waste generation and increase in the economic growth rate.

- Projection of future solid waste quantities is calculated by multiplying future population by future rate of per capita solid waste generation. (11)

Report on Feasibility Study and Preparation of the Terms for Reference and Bidding Document for the Construction of the incineration Plant not less than 1,000 tons/day capacity with Electricity Power Generation, BMA projected generation rate of solid waste base on assuming the growth rate of produced solid waste is as increasable as its historic trend. By Regression Analysis method, historic trend of generation rate was analyzed to formulate the following expression

$$Y = 0.0672X + 0.3011$$

Where Y : Generation rate of solid waste (kg/c/d)

X : Numbers of year as after B.C.2525

Japan International Cooperation (JICA) studied solid waste management in Bangkok in order to establish a modern solid waste management system for BMA in 1981. Their study carried out the quantitative estimation of solid waste from 1982 to 2000 that was predicted on the basis of historic trends of relation between solid waste generation volume and GPP. Such relation was formulated as the following linear equation. (12)

$$G = 5.64(P - 78.1) + 826$$

Where G : solid waste generation volume per year

P : Gross Provincial Products (GPP)

In other report from Feasibility Study on Management of Disposal of Bangkok Municipal Waste by National Energy Administration, BMA that looked upon the amount of solid waste generated in a given area as relation with the amount of materials of all type and consumed in the area. Residential waste generation rates usually increase as income levels rise. Increases in income level are, in turn, related to increases in the amount of commercial and industrial activity in an area. The GDP is then used to measure the industrial and commercial activity in study area, in order to determine the relationship between increase in it and increases in the solid waste generation rate. The daily metric tonnage of collected solid waste has been projected by multiplying the projected service population for study area by its the projected per capita disposal rate. (9)

As former section, solid waste generation is influenced from various factors that make for difficult estimating to consider all of them. By reviewing the relevant research of solid waste management, there is some way of solid waste' quantity projection which depend on the specified factors and assumption of researcher. The factors are generally expected to relate to solid waste generation are the changing of population and the changing of economic growth rate that will be also applied in this research.

2.1.3.2 Collection Efficiency

The collection efficiency had related to the optimum of collection crew, collection method and type of collection trucks that achieves the lowest cost of labor and vehicle. Studying collection efficiency, to be common knowledge in field is time motion study, have got to understand collection process that is generally composed the four following subsystem:

(1) Pickup, definition of which depends on the type of collection method used.

- For door-to-door or stationary system; pickup refers to the time spent loading of discharged waste onto a collection truck that begins with stopping the truck before loading the content of the first container and ending when the contents of the last container to be emptied have been loaded

- For hauled container systems, pickup refer to the time spent picking up the loaded container and the time required to redeposit the container after its contents have been emptied.

(2) Haul; the definition of the term haul also depends on the type of collection system used.

- For stationary or door-to-door system, hauling will start when the last container on the route has been emptied or the collection vehicle is filled and continuing through the time after leaving the unloading location until the truck arrives at the location of the first container to be emptied on the next collection route. However, it does not include the time spent at the location where the contents of the collection vehicle are unloaded.

- For hauled container systems, hauling will start after a container whose contents are to be emptied has been loaded on the truck and continuing through the time after leaving the unloading location until the truck arrives at the location where the empty container is to be re-deposited. This term also does not include any time spent at the location where the contents of container are unloaded.

(3) At-site refers to the time spent unloading of content from container or collection vehicle at processing or deposal site, including in-site travel time, i.e. the weighting time and waiting time.

(4) Off-route is the time spent for non-collection purpose and any other purpose that do not immediately relate the collection and transport work. Many of the activities associate with off-route time are sometime necessary of inherent in the operation. Therefore, the times spent on off-route activities may be subdivided in two categories are necessary, for example vehicle maintenance, vehicle washing, and routine reporting to the office, and necessary, such as lunch, breaks and so on. In practice, however, both necessary and unnecessary off-route time are considered together because they must be distributed equally over the entire operation.

Such process will be tracked to time a workload of which total time has been the following expression:

$$T = Tc + Th + Td + To$$

Where T = a total working time per day per crew

Tc = collection time

Th = transport time

Td = unloading time at destination

To = off-route time

2.1.3.3 Collection Cost

As former section, the component of collection system, especially vehicular collection, are principally the vehicles, the crews and, sometime, transfer station. So, the important factor must be considered are the type of vehicles, frequency and type of collection and length of routes. Each can have a significant impact on the cost of the operation. These imply two part of collection cost are the one related collection trucks and the other to be personnel expenses for workers. Therefore, collection cost per day per collection truck is expressed with the equation below. (12)

TC (Total cost) = M .k . L (operation and maintenance cost) + F . R . k . L (petrol cost) + V/t (vehicle depreciation) + S (wages)

Where	M = vehicle operation and maintenance cost	(Baht/km)
	F = petrol unit price	(Baht/liter)
	R = petrol consumption ratio	(liter/km)
	V = vehicle purchase cost	(Baht/unit)
	S = wages of the drivers and workers	(Baht/day)
	k = number of trip by a collection truck	(times/day/vehicle)
	L = mileage per trip	(km/trip)
	t = term of vehicle depreciation	(day)
	TC = total cost	(Baht)

Beside, a simple model of the average cost per ton can be written as the product of cost per unit time and collection time per ton as follow this: (10)

$$AC = \frac{TC}{Q}$$

Where : AC = average cost

Q = total tonnage collected

2.2 Operation Research

2.2.1 Definition

Operation Research (OR) is a scientific approach to the analysis of many kind of complex decision-making problem, such as economic, engineering or environmental problem, as encountered by individuals and organizations of all type. Its aim is the evaluation of probable consequences of decision choices, usually under conditions requiring the allocation of scarce resources, i.e. funds, manpower, time, or raw materials, as well as its objective is to improve the effectiveness of the system as a whole. (13)

In the other aspect, Management Science, which is OR to be referred in business field, is a rational, systematic approach to problem solving that employs quantitative analysis to help managers make decision. This approach uses quantitative tools and scientific methodology to management problem in order to develop and evaluate solutions. (14)

As these definitions, the principle concept of OR/MS is the using scientific method, which is rational and systematic approach, to analysis specific problem and evaluate probable solution in order to help decision makers make decision.

2.2.2 Process of OR/MS

The basic characteristic of OR/MS is its application of scientific method, its systematic approach, which is closely scientific methodology, can then be divided into the five following phases

- Formulation of the problem which identifying the components of a problem, i.e. decision maker, objects, alternative courses of action, and environment, will be obtained.

- Constructing a mathematical model to represent the operation studied: mathematical models that are the essence of the operations research approach to problem solving represent some entity of reality, such as a process, an operation, or a system. The purpose of a model is to explain, predict, or control the behavior of the entity modeled.

- Deriving a solution to the model: By mathematical model, a solution has to be derived. The optimal solution to a model has to be computed by numeric methods. The most powerful numeric methods are based on an algorithm that is a set of logical and mathematical operations performed in a specific sequence. The algorithm is applied to a given initial solution to the problem, to derive a new and ideally better solution.

- Testing the solution for performance: The purpose of testing the solution of the operation research is to ascertain that the decision rules derived from the optimal solution perform as expected and what the expected net benefits of implementing the solution will be. The test has to entail a detailed comparison of the actual performance of the optimal solution derived from the model, as if it were implemented, with the actual performance of present decision rules based on the same set of data. The actual operations would be based on the present decision rules; the new decision rules would be simulated on paper alongside the old ones.

- Implementing and maintaining the solution is putting the tested solution to work. This means translating the mathematical solution into a set of easily understood operating procedures or decision rules for each of the persons involved in using and applying the solution

2.2.3 The Operation Research on solid waste management (15)

The most planning of solid waste concerns with the problem of optimizing and or expanding existing system. The use of operations research techniques will enable a wide range of variables and alternative to be studied with a minimum of data collection. Some techniques that have been applied to solid waste collection are as follow this:

2.2.3.1. Monte-Carlo simulation: when an event is stochastic in nature the average value has very little significance except as an estimator of the long-term trend. The event itself is better described by the probability density function (pdf) which gives the relationship of the occurrence of one event with respect to another. Moreover, when the system is made up of a sequence of events, the probability distribution of the total time is difficult to define. Unless the pdf is a normal distribution, the sum of the averages does not give the average of the total distribution.

For example, the sum of events with exponential distributions is defined by a gamma distribution. The shape and properties of the gamma distribution is different from the exponential distribution.

Considering the collection system, it can be deduced that most of the variables are stochastic in nature. The stochastic or deterministic nature of a variable is dependent on whether the next event can be predicted without or with certainty. If the next event can only be expressed in terms of chance of occurrence, then it is stochastic. For example, in a residential area some houses may have one waste container, some 2, some 3, and some 4 or more. Before the next collection stop is reached, the exact number of containers cannot be known but, from previous studies, it may be possible to predict that 50 per cent of the time there will be one container, 25 per cent of the time 2 containers, etc., so that the variable is stochastic. After the sequence of operations has been developed and identified, field studies can be designed to measure and define the measures of the variables. The practical experiment can be conducted by following a collection crew for a number of days in different types of collection areas and recording the values of the variables. Statistical analysis of the collected data is then carried out to determine the pdf.

A simulation model can be constructed by generating random varies for the different distributions. The first important step after the model has been developed is to compare the output of the model with actual field data. If the results are close to each other, say error is less than 5 per cent, them the model is said to be validate.

After validation, the variables that could the controlled by the organization, such as truck size, collection type, are varied. This is known as the sensitivity test and the purpose is to identify those variables which have the greatest effect on the system. The management will then have an idea of which variables should be watched closely and which could be taken for granted. In this way a supervisory routine of inspection and reporting could be better developed.

2.2.3.2. Linear Programming: All linear programming techniques are most often used for allocating scarce resources among competing alternatives. The resources may be time, product availability, labor force limitations, and so on. The alternatives may be the production of different products, the selection of different investment strategies, production plans, ingredients in cattle feed, and so on. In most cases, linear programming either maximizes profits or minimizes costs without using more scarce resources than are available. The main application of linear programming in solid waste management is in the allocation of trucks and men to different collection areas such that the cost of collection and disposal is minimized for the whole city.

2.2.3.3.Queuing theory: Time is a limited resource, which can never be recovered, that is most lost in waiting in line. For example, waiting in line at grocery stores, bank, theaters, traffic lights and so on. These losses of time imply the cost, especially in manufacturing process, to expend for works and effectiveness of service. By reducing the amount of time, cost could be reduced and customer service improved. The queuing theory, in management science terminology, represents the body of knowledge dealing with waiting lines.

In solid waste management, Queuing theory has found application in design of unload facilities at a disposal site. Most often the regular working day starts simultaneously for all crews but, since they are sent to collection areas at varying distances from the disposal site, they arrive at the disposal site at different time of day. Sometimes a large number of trucks will arrive at the disposal site simultaneously, when some will have to wait in line while the other trucks are unloading. In this case, waiting trucks will mean time lost in the utilization of crew and truck. However, increasing the number of unloading facilities at the disposal site will also mean an increase in the cost of construction for the disposal site. By Queuing theory, standard mathematical formulate have been developed to predict the number of trucks waiting and the average waiting time for the trucks. The cost of the waiting trucks can be estimated from the idle labor and equipment. When the idled times of machines and manpower decrease the cost will also be decreased.

2.3 Information System

2.3.1 Definition

There are quite a number of different definitions upon the way of conceptual. Some of them emphasize what data and information process are and whether that system is based on computer system or not; according to Ralph M. Stair's description, "an information system is a set of interrelated elements or components that collect, manipulate and store, and disseminate data and information as well as a feedback mechanism". His information system term is to refer to such a system that can be either manual or computerized. (16) Some other definitions instead focus on providing information to support an organization like the one Henry C. Lucas specified, "an information system to be a set of organized procedures that, when executed, provides information to support the organization" (17)

From all above definitions, it can be comprehensively concluded with the definition by Kenneth C. Laudon and Jane P. Laudon for computer-based information system as follows:

An information system can be defined technically as a set of interrelated components that collect (or retrieve), process, store and distribute information to support decision making, coordination, and control in an organization. (18)

2.3.2 Structure and component of information system

An information system is defined as components that work together to provide desired information in the proper format at an appropriate time. An organization may have many different information systems and subsystems, be they manual or computerized or both combined depending on its use of information technology to serve its own purposes. Information technology refers to the computer equipment itself and whatever is stored in it, programs and data. An information system is developed to use this technology effectively to meet an organization need. So the primary components necessary to have a working information system include people to operate or use the system, procedures, and information technology, which include hardware, software, and data that is to be processed through the system. (19) The relationship among the components and activities of information systems are shown in figure 2-2

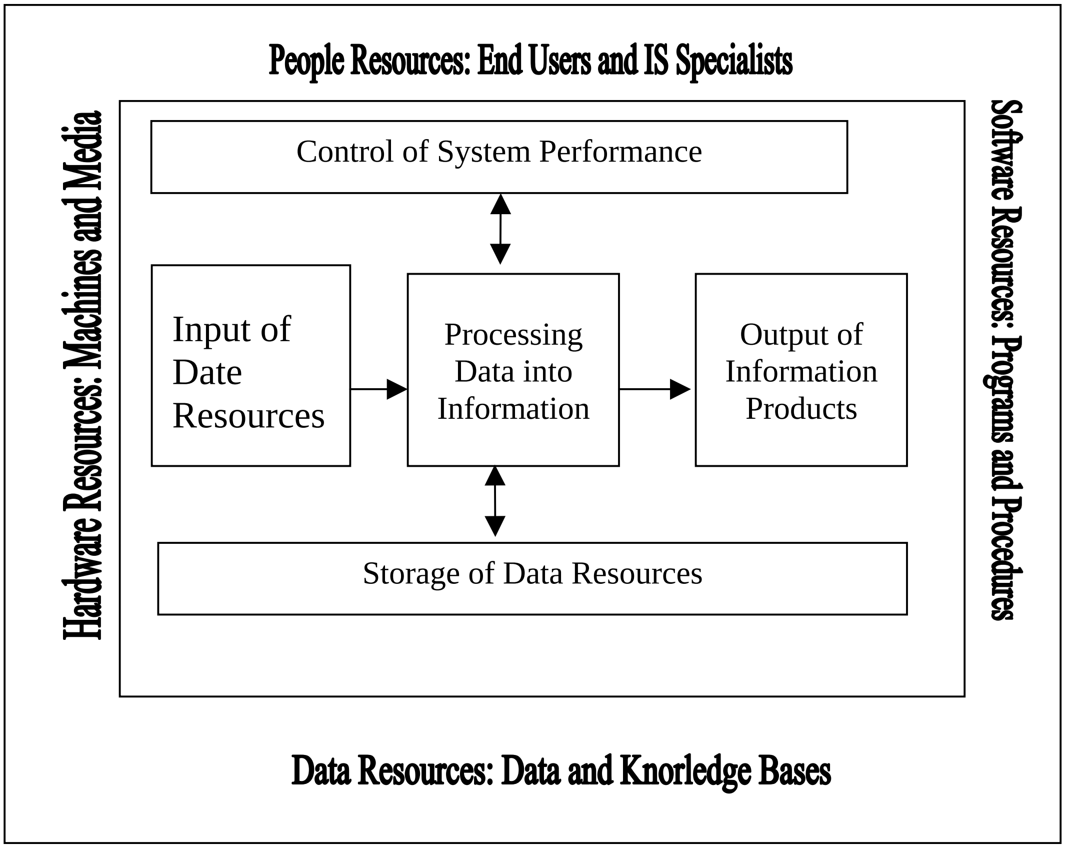

Figure 2-2 The components of an information system and their performance.
Source: Management Information Systems Managing Information Technology in the Networked Enterprise, 1998

2.3.3 Systems development

A new information system is built as a solution to some type of problem or set of problem the organization perceives it is facing. The activities that go into producing an information system solution to an organization problem are called systems development. These activities consist of systems analysis, system design, programming, testing, conversion, and production and maintenance. (18) Due to systems differ in terms of their size and technological complexity, and in terms of the organizational problems they are meant to solve. So there are a number of methods have been developed to build systems. A common methodology for system development in many organizations is the system development life cycle (SDLC) whose system analysis and design phase is following below

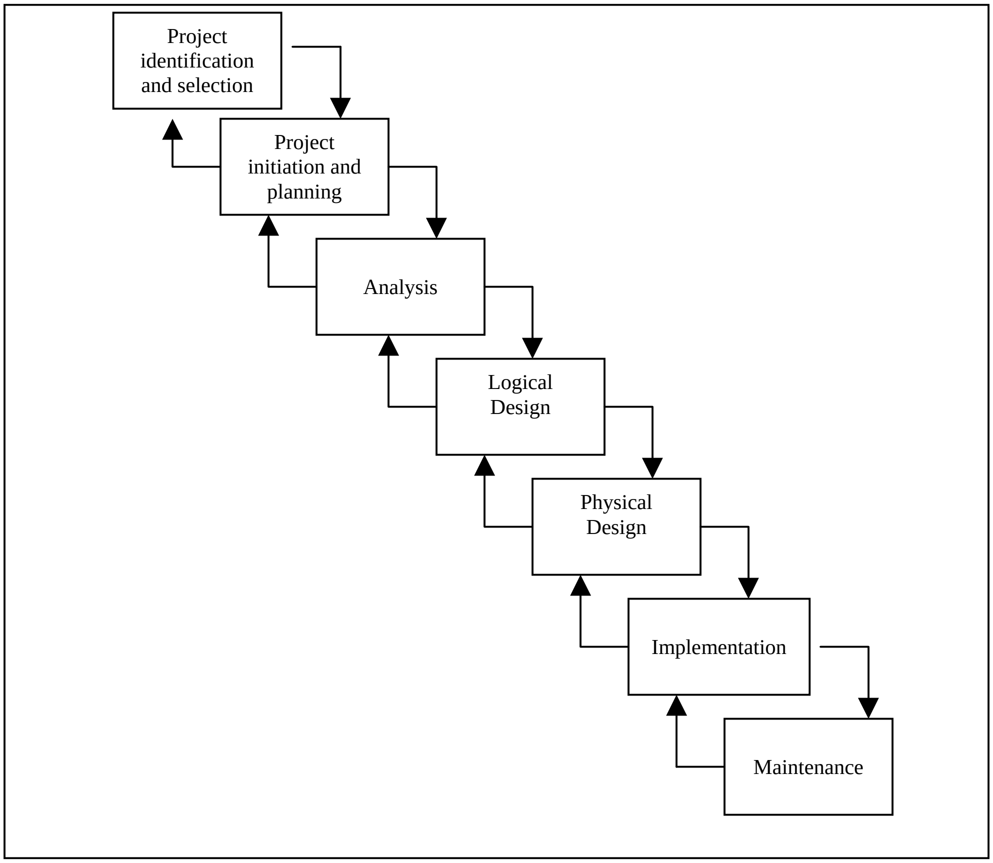

Figure 2-3 The system development life cycle

Source: Modern Systems Analysis and Design Second Edition, 1999

2.3.4 Systems analysis

Systems analysis is the analysis of the problem that the organization will try to solve with an information system. It consists of defining the problem, identifying its causes, specifying the solution, and identifying the information requirements that must be met by a system solution. The purpose of analysis is to determine how the current information system function and assess what information and information processing services are needed to support objects and functions of organization. An analysis is an extensive process which can be divided into the following main activities.

2.3.4.1. Requirements determination; this is primarily a fact-finding activity by collecting information about the information system that are currently being used and how users would like to improve the current systems with new or replacement information system. The result of requirements determination is a thorough set of information that describes the current system being studied and the need for new and different capabilities to be include in the replacement system. However, this information is not in a form that makes analysis of true problems and clear statements of new features possible. There are necessary to study this information and structure it into standard formats suitable for identifying problems and unambiguously describing the specifications for new systems.

2.3.4.2. Structuring system requirement is an activity that creates a thorough and clear description of current operations and new information processing services. By using modeling technique, the results of the requirements determination can be structured according to three essential views of the current and replacement information system namely

(1) The process view of a system; this view is process and the sequence of data movement and handling operation within the system. It can be represented by process modeling, a common form of which is a data flow diagram, involves graphically representing the function, or process, which capture, manipulate, store, and distribute data between a system and its environment and between components within a system.

(2) Logic and timing views show the rules by which data are transformed and manipulated and an indication of what triggers data transformation. By using logic modeling represents the logic contained in a data flow diagram's processes as well as the contents and structure of data flow diagram's data flow and data stores. There are three methods of modeling techniques. The first one, Structured English, is a special form of spoken English to illustrate the logic of process depicted in data flow diagrams. The other two, decision tables and decision trees, are graphical methods for representing process logic. With one of these methods**,** the primary deliverables are structured descriptions and diagrams that outline the logic contained within each data flow diagrams that show the temporal dimension of system, i.e. when processes or events occur and how these events change the state of the system. This is critical result because process must be clearly described before they can be translated into a programming language.

(3) The data view of system shows the rules that govern the structure and integrity of data and concentrates on what data about entities and relationships among these entities must be accessed within the system. This view can be represented with using data modeling which is a technique for organizing and documenting a system's data. The most common format used is entity relationship (E-R) diagram to depict data in terms of the entities and relationships described by the data.

2.3.5. Systems design

Systems design is defined as those tasks that focus on the technical or implementation concerns of the system. It is like a blueprint of the computer-base system to be programmed. This phase includes development of logical design and physical design.

2.3.5.1. Logical design is often developed to be a concrete understanding of how the system will operate. During logical design all system is defined the look and feel of its input, output, and interfaces and dialogues as well as supplements the conceptual data model from the analysis phase with new data requirement. Logical design includes the following steps

(1) Designing forms and reports; in general, forms are used to present or collect information on a single item and can be used for both input and output. Reports, on the other hand, are used to convey information on a collection of items. The goal of form and report design is usability. Usability means that users can use a form or report quickly, accurately, and with high satisfaction. To be usable designs must be consistent, efficient, self-explanatory, well formatted, and flexible.

(2) Design interfaces and dialogues; Interface design focuses on how information is provided to and captured from users, while dialogue design focuses on the sequencing of interface displays. The design of interfaces and dialogues is the process of defining the manner in which human and computers exchange information. A good human-computer interface provides a uniform structure for finding, viewing, and invoking the different components of a system.

(3) Logical data modeling; logical data model describes data using a notation, which corresponds to a data organization used by a database management

system. The most common style for a logical data model is the relational database model that represents data in the form of tables or relation of data in which cell has an atomic value. Data modeling during analysis is done using entity-relationship modeling which uses a special notation to represent as much meaning about data as possible. In logical design ER-diagram is processed to call normalization, which is a way to build a data model that has some desirable properties of simplicity, non-redundancy, and maintenance.

2.3.5.2. Physical design is based on the logical design and involves the actual design of all aspects of the system. The purpose of physical design is to specify all the technological characteristics of the system so that those involved in the implementation phase can concentrate on building the system. Physical design specifies the structures for data and programs that will make the system work efficiently and securely, including considerations for the location of data and data processing on a computer network. (21)

2.3.6 Quality of information

Information is data that has been converted into a meaningful and useful context for specific end users. Thus, data is usually subjected to a value-added process where

- Its form is aggregated, manipulated, and organized.
- Its content is analyzed and evaluated and
- It is placed in a proper context for a human user. (22)

Even if information is presented in such a way as to be transmitted efficiently and interpreted correctly, it may not be used effectively. The value of information is in motivation, model building, and background building affecting future decisions and actions. The quality of information is determined by how it motivates human action and contributes to effective decision-making that is discussed in term of utility and error of information. (23)

2.3.7 Utility of information

Information may be evaluated in terms of utilities that, which may facilitate or retard its use, is identified four information utilities namely

(1) Form utility. As the form of information more closely matches the requirements of the decision maker, its value increases.

(2) Time utility. Information has greater value to the decision maker if it is available when needed.

(3) Place utility or physical accessibility. Information has greater value if it can be accessed or delivered easily. Online systems maximize both time and place utility.

(4) Possession utility or organizational location. The possessor of information strongly affects its value by controlling its dissemination to others.

2.3.8 Errors of information

Error is a more serious problem because there is no simple adjustment for it. Error may be a result of:

- Incorrect data measurement and collection methods
- Failure of follow correct processing procedures
- Wrong recording or correcting of data
- Loss or no processing of data
- Incorrect history or master file
- Mistakes in processing procedure, such as computer program errors
- In most information system, the receiver of information has no knowledge of error that may affect its quality. The difficulties with errors may be overcome by

- Internal controls to detect errors
- Internal and external auditing
- Addition of confidence limits to data
- User instruction in measurement and processing procedures, so users can evaluate possible errors

2.4 Database system

2.4.1 Definition and component of database system

A database system is a computerized system whose overall purpose is to store information, or data, and to allow users to retrieve and update that information on demand. The information or data can be anything that is of significance to the individual or organization concerned. (24) The collection of data is usually referred to as the database. In the other words, a database is a collection of persistent data that is used by the application system of some given enterprise. Database systems are designed to manage large bodies of information. Management of data involves both defining structure for storage of information and providing mechanisms for the manipulation of information. So a database-management system (DBMS) is a collection of interrelated data and a set of programs to access those data. (25)

2.4.2 Database System Architecture

Database system is a collection of interrelated files and a set of programs that allow user to access and modify these files. A major purpose of a database system is to provide users with an abstract view of the data, which of the ANSI/SPARC architecture is divided into three levels namely

(1) The physical or internal level is lowest level of abstraction describes how data are stored. At this level one describes how the data is stored on storage devices and in which file organization. It is the level of bits, bytes, disk blocks and so on, the level at which processing is actually done.

(2) The logical or conceptual level is the next-higher level of abstraction describes what data are stored in the database, and what relationships exist among those data. The logical level thus describes the entire database in terms of a small number of relatively simple structures, logical concepts such as entities, attributes and relationships. The design of the conceptual level is known as a conceptual data model. There are many methodologies for defining conceptual models, for example, the entity-relation model supplies a methodology for producing a conceptual model whose deliverables are called entity-relationship diagrams.

(3) The view or external level is the highest level of abstraction describes the subsets of data which individual users may require. Most user are

concerned only with a part of the entire database. Their interaction with the whole can be simplified by presenting the database in terms of their partial views of the whole. The system may provide many view for the same database. (25), (26)

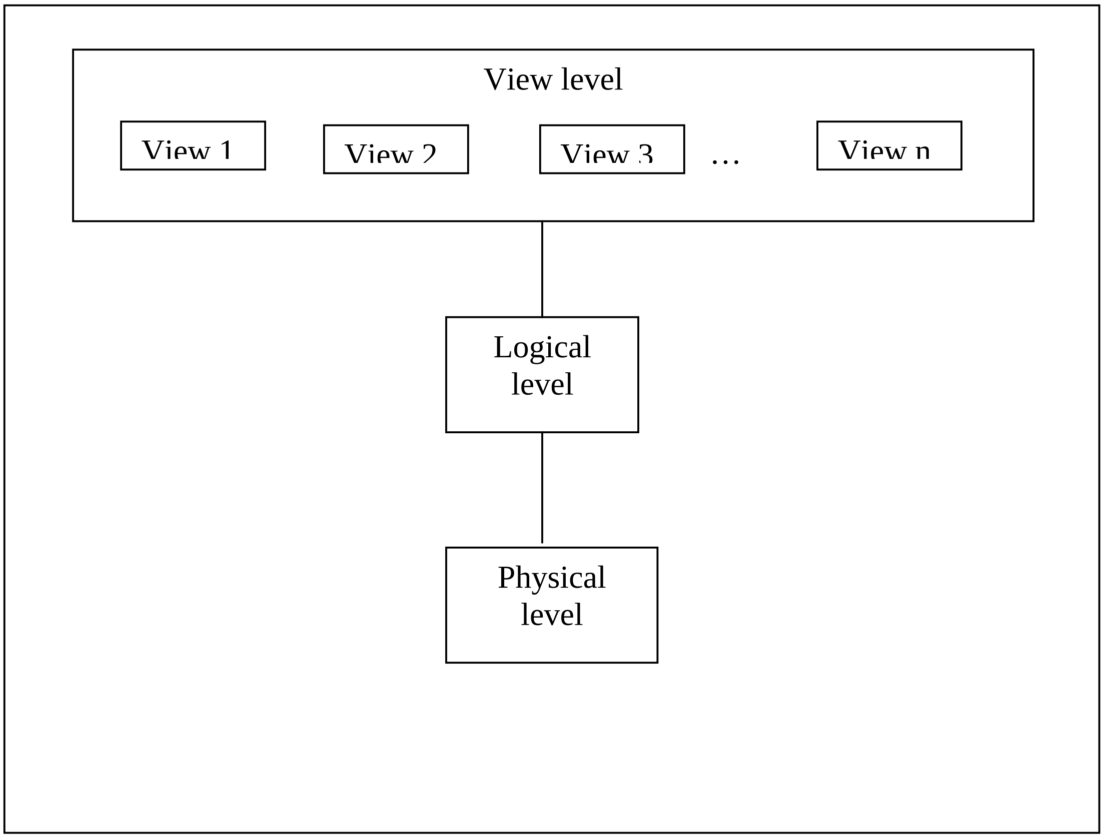

Figure 2-4 The relationship among the three levels of abstraction.
Source: Database System Concepts 4TH Edition, 2002

2.4.3 Data Models

A data model is a collection of conceptual tools for describing data, data relationships, data semantics, and consistency constraints. There are commonly two data model. The one is the entity-relationship (E-R) model, which is based on a perception of a real world that consists of a collection of entities and of relationships among these entities. The other is the relational model to uses a collection of tables to represent both data and the relationships among those data. Designing database often formulate database schema design by first modeling data at a high level, by using the

E-R model, and then translating it into the relational model, which is a lower-level model. (25)

2.4.3.1 Entity-Relationship Model; The entity-relationship (E-R) data model perceives the real world as consisting of basic objects, called entities, and relationships among these objects. It employs three basic notions, i.e. entity sets, attributes, and relationship sets, including mapping cardinalities and key to present the overall logical structure of database.

2.4.3.2. Entity set; an entity is a "thing" in the real world that is distinguishable from all other one. A "thing" includes objects and concepts including event, activities and states that are important to the organization and about which it wishes to keep information other than solely what the thing is. An entity set is a set of entities of the same type that share the same properties.

2.4.3.3. Attributes; an entity is represented by a set of attributes. Attributes are descriptive properties processed by each member of an entity set. The designation of an attribute for an entity set expresses that the database stores similar information concerning each entity in the entity set, however, each entity has a value for each of its attributes.

2.4.3.4. Relationship sets; a relationship is an association among two or more entities which is meaningful to the organization and that in conformity with the organization's wishes, must be recorded.

2.4.3.5 Mapping cardinalities; or cardinality ratios, express the number of entities to which another entity can be associated via a relationship set. They are most useful in describing binary relationship sets.

For a binary relationship set between two entities set, assume to be entity set A and B, the mapping cardinality must be one of the following:

- One to one. An entity in A is associated with at most one entity in B, and an entity in B is associated with at most one entity in A.

- One to many. An entity in A is associated with any number of entities in B. An entity in B, however, can be associated with at most one entity in A.

- Many to one. An entity in A is associated with at most one entity in B. An entity in B, however, can be associated with any number of entities in A.

- Many to many. An entity in A is associated with any number of entities in B, and an entity in B is associated with any number of entities in A.

2.4.3.6 Key; Due to individual entities are conceptually distinct, so they must to be distinguished. The way specifies the difference among them can be expressed in term of their attribute. Therefore, the values of the attribute values of an entity must be such that they can uniquely identify the entity. A set of attributes as the identifier of an entity is referred a key term.

The E-R model can be expressed by an E-R diagram, which uses the important symbols as show in this figure

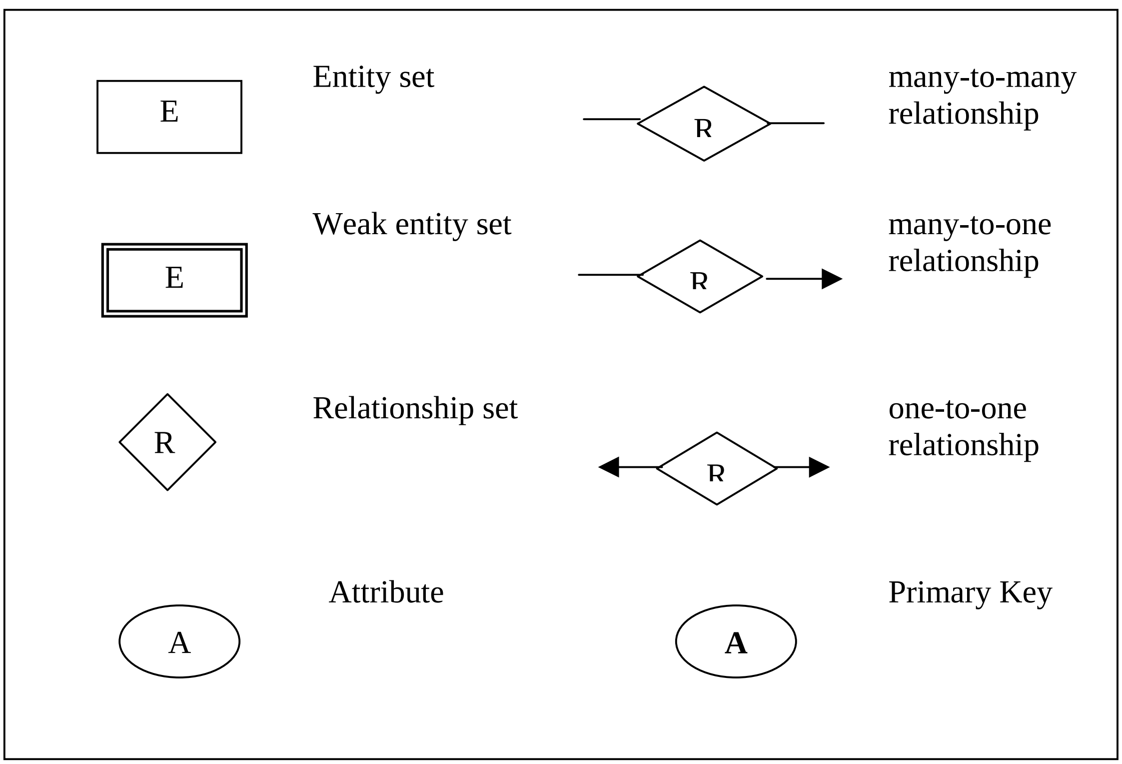

Figure 2-5 Symbols of the E-R diagrams

Source: An Introduction to Database System Seventh Edition, 2000

2.5 Pertinent Research

Nuttanit Silidul studied to locate an optimal site of transfer station for solid waste collection system of Nothaburi Municipality. By Linear Programming technique, one of three sites selected together with allocating optimally capacity of transfer station to dump waste based on minimizing operation cost of collection system. From research, the selected site was the one locate far from existing disposal site about 35 kilometers with the design capacity of transfer station at 203.20 ton per day.

Marcus M. Truitt, Jon C. Liebman, and Cornelius W. Kruse: their research are concerned with mathematic model which simulate the working and operation of residential solid waste collection system in the City of Baltimore. This study has prepared mathematical simulation models that allow comparison of costs of solid waste collection between two different operation policies; that is to increase collection frequency from semiweekly to tri-weekly. The research' result indicated that cost increasing were found to be from 10 % to 25 % depend on considering the relative weights on the design capacity of the disposal points.

Ely Anthong Rosales Ouano studied about model development and economic evaluation for solid waste collection and disposal. Base on the crew utilization study, the computer simulation model was developed. Various variations utilizing a two-man crew, centralized collection points with the same number of crews or increased number of crew were developed. Equation for the decision criteria, of taking another trip to the collection area after a number of trips have been completed for the day, were also developed. The cost equations for the present system and proposed system using larger trucks were developed. The generation of random varies to correspond to the different probability distributions encountered in the study were reviewed.

Paisan Padungsirikul researched on Municipal Solid Waste Management in Nonthaburi Province. This research analyzed problem condition and planned solid waste management. The result of study presented quantity of solid waste will be up to 427 tons/day in Nonthaburi Municipality, 39 tons/day in Bangbuatong, and 193 tons/day in Parkret. Researcher recommended transfer station should be constructed to reduce collection time that implies consuming fuel and maintenance cost. Additional, sanitary landfill was recommended for solid waste disposal, which requires at least area 307 rai.

Nuanwan Traksa studied on The Geographic Information System Application in Solid waste Management Planning Case Study: Pathum Thani Province that applied the geographic information system (GIS) in the area of solid waste management planning. GIS database were created and stored in spatial data forms that can be updated, edited and modified as well as displayed spatial data of the real world. In this study the overlay technique and merge solid waste quantity was presented for the entire waste source

CHAPTER III
MATERIALS AND METHODS

To conduct a study on decision support system for planning upon the collection truck providing, that give decision maker preliminary information about cost for providing the purchasable and the rental collection trucks as well as the overview of collection cost, the materials and methods used in this study consists of details as follows:

3.1 Materials and Instrument

3.1.1 Personal Computer with the capacity at least Pentium 2 up and operating by window 2000 and having main memory not less than 64 MB.

3.1.2 The three following Application Software are utilized to develop this research:

- Data Base Management System (DBMS) application software, i.e. Access, is adopted to structure Solid Waste Management Database.
- Spreadsheet Software, i.e. Excel, is employed to solve the equations.
- LIDO API is utility software to solve Linear Programming problem.
- Visual Basic software is applied to provide the user interface.

3.2 Data Resource

Secondary data are collected from study reports, researches, and official statistic data, which consist of the following data

3.2.1 Territorial and population data are collected from the Department of Policy and Planning, Bangkok Metropolitan Administration (BMA).

3.2.2 Solid waste management data are collected from the Department of Public Cleaning, BMA details as follows:

- Quantities of collected and disposed waste
- Cost of waste collection and disposal.

- The use of resources, such as workers, equipments, and budget, handle with all waste.
- Rental cost of collection truck.
- Time motion study data.
- Policy of waste collection

3.2.3 Economic data are collected from the National Economic and Social Development Board.

3.3 Method

There are three parts to be focus on this study namely modeling, constructing information system and analyzing optimal numbers of purchasing and renting collection truck of BMA. The first two parts are the methods for constructing the Decision Support System (DSS) for planning on the collection truck providing and the last one is to find out the solutions for BMA's problem on providing collection trucks by using this created Decision Support System model. Theirs details are as following;.

3.3.1 Modeling

In the analysis part, Decision Support System for the solid waste collection planning composed of three principal models that are the estimation model of solid waste quantity, the calculation model of collection truck number and the Linear Programming model. Of which processes are orderly presented as shown in figure 3-1.

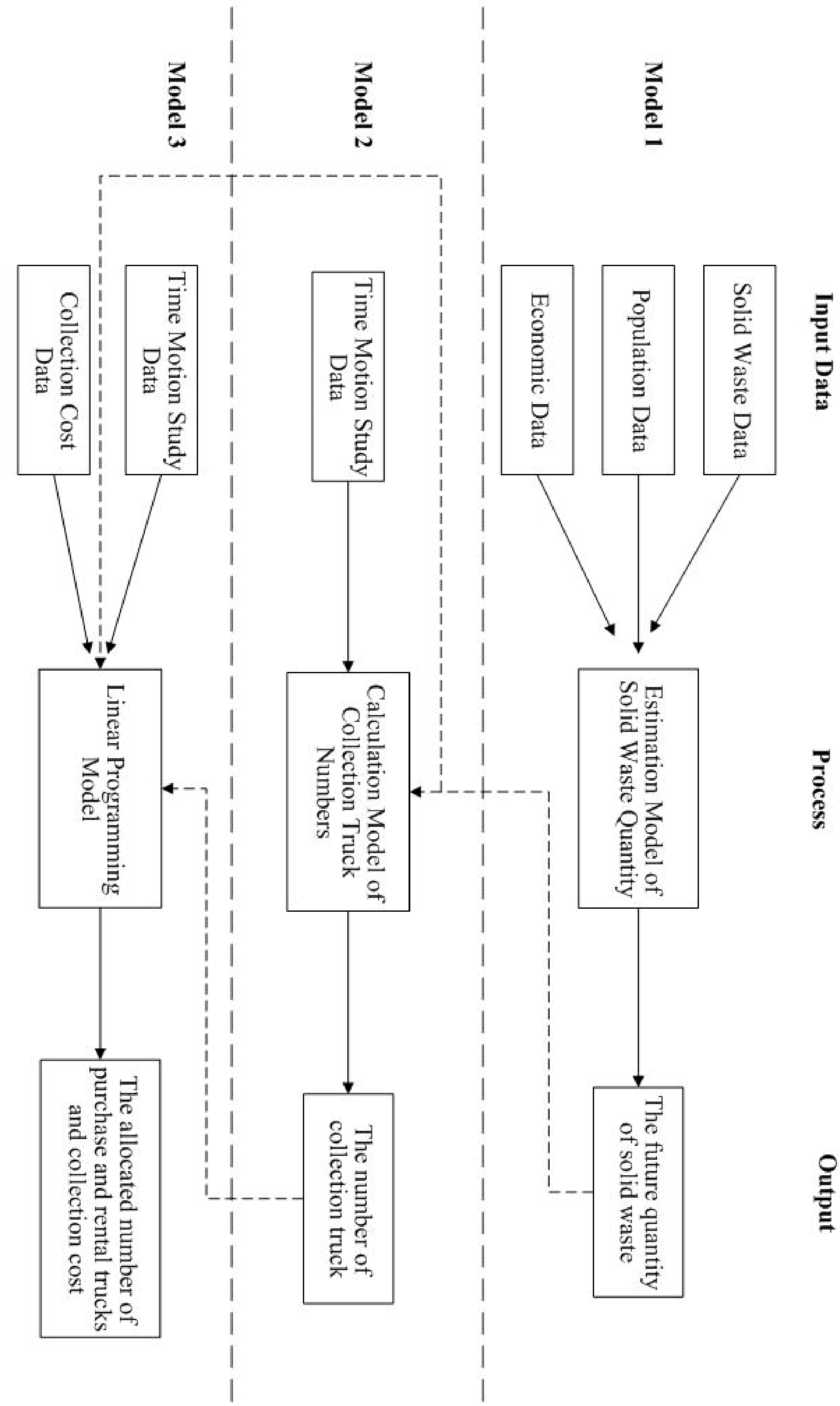

Figure 3-1 Conceptual process of the decision support system for the procurement of MSW collection truck's model

3.3.1.1 Quantitative Estimation Model

Estimating of the future quantitative profile of municipal solid waste depends on factors related to waste generation and their variety. As literature review, the general factors used to forecast the future quantity of waste are population and economic factor. According to the population and the Gross Domestic Product (GDP) data since B.E. 2528 – 2539, their results were plotted on graph as shown in figure 3-2. It was clearly illustrated that the trends of these two factors were on the same direction.

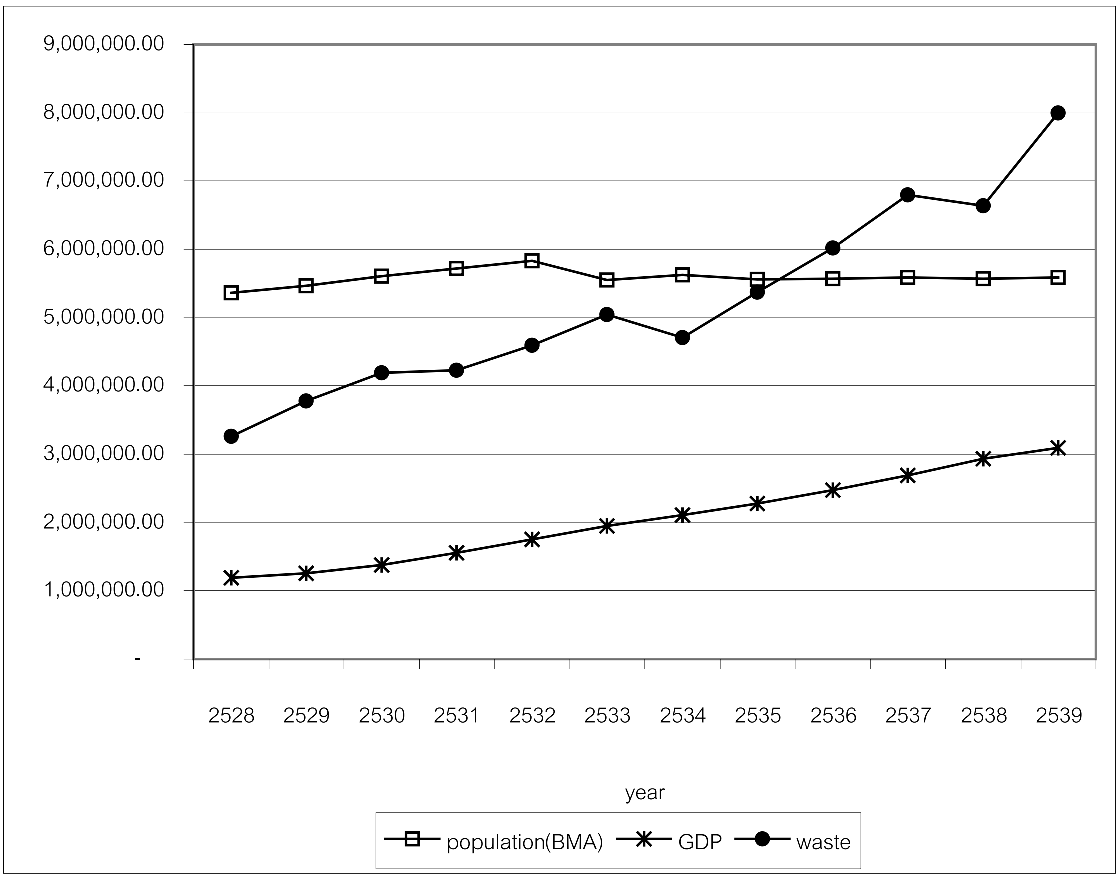

Figure 3-2 Trend of the change in population, GDP and waste quantity since B.E. 2528 – 2539.

Source Population data from Department of Policy and Planning, BMA.

GDP data from National Economic and Social Development Board.

Waste quantity from Department of Public Cleaning, BMA

The future quantity of municipal waste can be forecasted by the following equation; (16)

$$G = W \times P_n$$

Where G = The future quantity of waste

W = Future generation rate of municipal waste

P_n = Future number of population

Following this equation, there are two variables, i.e. the future generation rate of waste and the future population, to be found out as following details,

3.3.1.1.1 Future Generation Rate of Municipal Waste: this study will estimate the future generation rate of municipal waste base on the historic trends of the relation between municipal waste collection volume per capita per day and GDP per capita of Bangkok since B.E. 2528 – 2539 as shown in table 3-1 and table 3-2. By using the Linear Regression, their relation will formulate the equation of quantity estimation as the following general form:

$$Y_i = \beta_0 + \beta_1 X_i$$

Table 3-1 Municipal waste collection volumes per capita per day and GDP per capita of Bangkok since B.E. 2528 – 2539

Year	Population* (Capita)	Waste** (*1000kg/Day)	Waste (Kg/cap/day)	GDP*** (Bath/cap/year)
2528	5,363,378.00	3,260.22	0.61	22999.13
2529	5,468,915.00	3,782.64	0.69	23734.11
2530	5,609,352.00	4,190.09	0.75	25557.19
2531	5,716,779.00	4,224.85	0.74	28380.24
2532	5,832,843.00	4,597.70	0.79	31311.55
2533	5,546,937.00	5,044.80	0.91	34551.67

Table 3-2 Municipal waste collection volumes per capita per day and GDP per capita of Bangkok since B.E. 2528 – 2539 (continued)

Year	Population* (Capita)	Waste** (*1000kg/Day)	Waste (Kg/cap/day)	GDP*** (Bath/cap/year)
2534	5,620,591.00	4,706.03	0.84	37075.56
2535	5,562,141.00	5,372.17	0.97	39498.41
2536	5,572,712.00	6,015.65	1.08	42408.36
2537	5,584,226.00	6,798.28	1.22	45605.13
2538	5,570,743.00	6,633.71	1.19	49329.79
2539	5,584,963.00	8,000.86	1.43	51484.32

Source *Data from Department of Policy and Planning, BMA

** Data from Department of Public Cleaning, BMA

*** Data from Office of the National Economic and Social Development Board

3.3.1.1.2 Future Population: there are several methods for forecasting the future population, of which the mostly used in waste management field is to explain historical trend profile of population variation by plotting a graph. A closely curve outline on a graph will be stated as equation used to estimate the future population. However, Bangkok's registration number of population is not exact amount since there are several millions of hidden people lived in it, accordingly , this method may not be appropriated. Other method, is to consider on the urban development prospect. To this contemplation, Bangkok has a potential to develop on physical geography, economy and society that appear with increasing of land use and density of construction in central area. Thus, the appropriate model of forecasting the Bangkok's population should be expressed in an exponential model as follow: (17)

$$P_n = P_o (1 + r)^n$$

Where P_n : numbers of future population

P_o : numbers of present population

r : variant rate of population (percent)

n : term of accounted years

3.3.1.2 Calculation Model of Collection Truck Numbers (12)

The required numbers of vehicle and worker in operating waste collection are derived from daily work volume. According to the collection process, total times required for waste collection can be computed as follows this equation:

$$T = Tc + Th + Td + To \qquad \text{(Eq. 3.1.2 – 1)}$$

Where T : a total working time per day per crew

Tc : collection time

Th : transport time

Td : unloading time at destination

To : off-route time

Collection time (Tc) includes the time for loading of discharged waste onto a collection truck and traveling from one collection point to the next. Therefore, a collection time is defined with an equation below.

$$Tc = Tl + Tm = (16.7) \times Q \times El + Q \times Em \qquad \text{(Eq. 3.1.2 – 2)}$$

Where Q : Collection volume (tons/day)

Tl : Loading time (minute)

El : Loading efficiency (sec/kg)

Transport time is expressible with number of trips per day and transport time per round trip to the destination as follows this:

$$Th = \frac{Q}{q} \times t_h \qquad \text{(Eq. 3.1.2 – 3)}$$

Where q : Loading volume per trip (ton/trip)

t_h : Transport time per round trip to destination (minute/round trip)

Unloading time is the time needed for unloading of solid waste from collection truck at a processing or disposal site, including in-site travel time, weighing time and waiting time. Unloading time per trip is expressed with the equation below.

$$Td = \frac{t_d}{q} \times Q \qquad \text{(Eq. 3.1.2 – 4)}$$

Where t_d : Unloading time per trip (minute/trip)

Solid waste collection volume per day per crew is obtainable by inserting the value from the above equation 3.1.2 – 2, 3.1.2 –3 and 3.1.2 – 4 into equation 3.1.2 – 1 with the following results:

$$Q = \frac{q \times (T - To)}{q\,(16.7\ El + Em) + (t_h + t_d)} = \frac{q \times Te}{q(16.7\ El + Em) + (t_h + t_d)} \qquad \text{(Eq. 3.1.2 – 5)}$$

Where Te : effective working time (minute)

Collection volume per vehicle per day obtained by Eq. 3.1.2 – 5 is under collection efficiency that can be used to calculate the required trucks follow this equation:

$$N = (1+\alpha)\frac{G}{Q}$$

Where N : The required number of collection truck

α : coefficient of spares

G : the maximum planned collection volume per day (tons/day)

3.3.1.3 Linear Programming Model

From title of solid waste management plan in Bangkok Development Plan Letter 6 and TOR (Term of Reference) for the Compactor Trucks Renting Project of BMA. It could be defined that the principle collection policy is to maximize the collection efficiency through cost minimizing. However, an important difficulty faced by BMA is the utilization of the old collection trucks which most of which have been used over seven years that bring about high maintenance cost. This situation disagree with such policy. Hence, instead of purchasing new trucks, BMA exploit to rent private collection trucks to replace some of those old trucks while the budget is restricted. This choice is considered high capital cost compare with the purchasing but it overwhelm by its zero maintenance. Therefore, considering the former policy, the key obscurity of planning on providing the collection trucks is what the appropriate number for purchasing and rent are? This indistinctness can be straightforward by applying the Linear Programming as the following general form:

MAX (or MIN) $c_1X_1 + c_2X_2 + \ldots + c_nX_n$

Subject to: $a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n \le b_1$

$a_{i1}X_1 + a_{i2}X_2 + \ldots + a_{in}X_n \ge b_i$

$X_n \ge 0$

Where $X_1, X_2, \ldots, X_n$ are decision variable.

$c_1, c_2, \ldots, c_n$ are objection function coefficients.

$a_{i1}, a_{i2}, \ldots, a_{in}$ are the numeric coefficient in the i th constraint for variable X_n

$b_1, b_2, \ldots, b_i$ are constraints.

3.3.2 Constructing Information System

3.3.2.1 System analysis and design, the following tools are chosen to develop information system:

(1) The Data Flow Diagram will be chosen for modeling system process to show how data flow throughout the information system and their relationship while flowing.

(2) Database system that is of Relation Database nature will be designed by using Entity-Relation data model that showing the data details, their logical representation and relationship.

(3) To design interface by which users interact with an information system that emphasizes user friendly.

3.3.2.2 Information system comprises two main parts. One is the solid waste management database to be constructed via Microsoft Access program. The other is a calculation model to be constructed via Microsoft Excel for computing equation and Lindo API to solve the Linear Programming problem. Visual Basic program draws up the user interface of the entire information system, as well as programs process of information system.

3.3.2.3 System testing involves crosscheck data test and scenarios to ensure that each component and the whole system work under the normal circumstances.

3.3.2.4 To prepare a handbook to illustrate how the system works and how to run it including data dictionary as a guideline for further system development.

3.3.3 Analyzing optimal numbers of purchasing and renting collection truck of BMA

By this created decision support system, the actual waste collection data of BMA and other related data will be inputted and processed to find out optimal numbers of the purchased trucks and the rental trucks, as well as the collection cost caused by them, that is the primary information to support decision making on providing the collection trucks.

3.4 Evaluation

Attitude measure questionnaire of Licurt, which their choices divided into 5 levels, very good, good, fairly good, poor and bad. The questionnaire is used for measure how users appreciate on the system efficiency and the user friendly by sending a questionnaire to the target group. If 80 percent of 10 users weigh up their appreciation for this system on good level, then, this evaluation will be accepted pass.

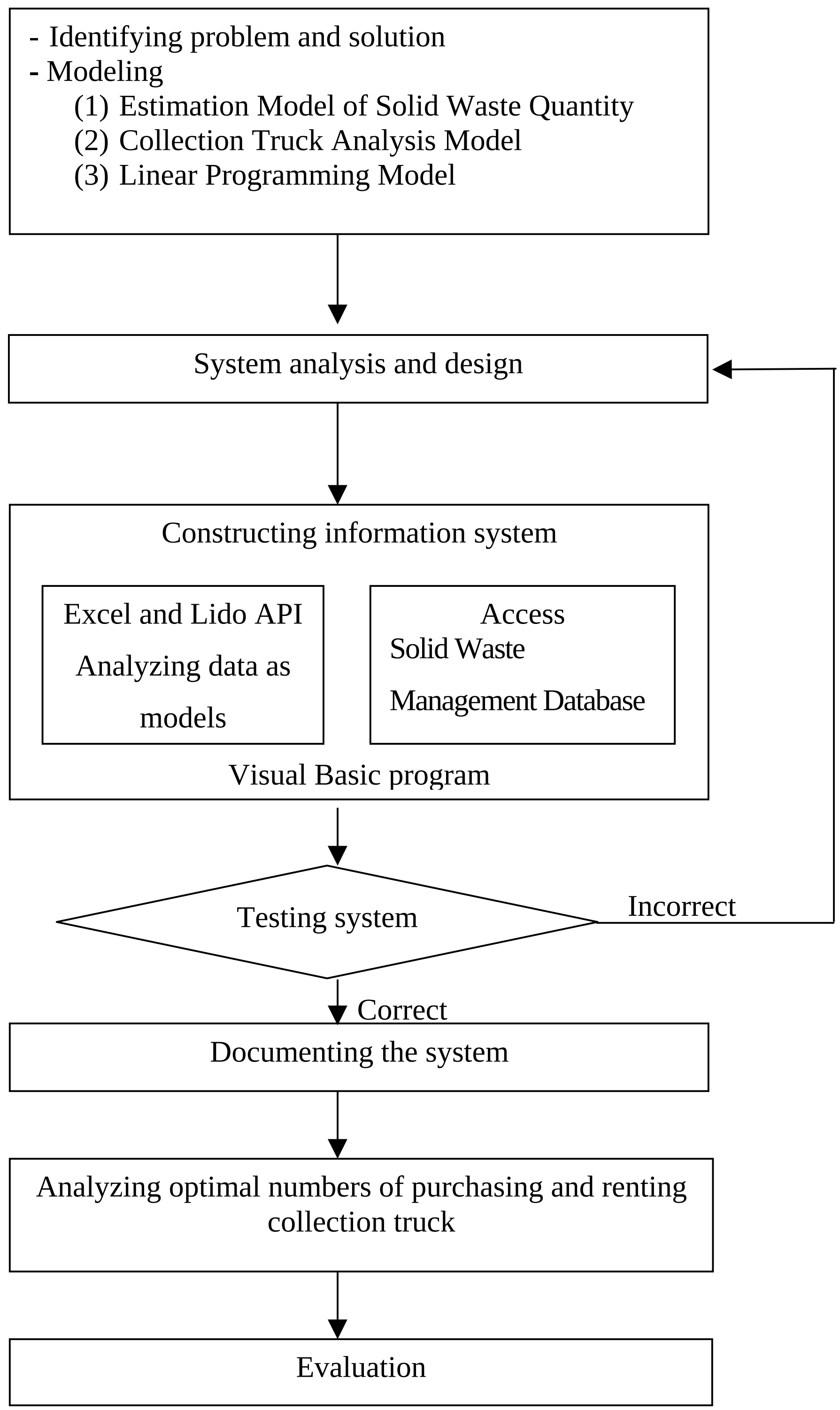

Figure 3 – 3 Methodology Chart

CHAPTER IV
RESULTS

This section detailed three parts of this research output namely the constructed model, the DSS for the procurement of MSW collection trucks and output of the this DSS process. For the first part, all mathematic models to be included in this research will be described their assumptions and conceptions. The second part is the structuring of the DSS for the procurement of MSW collection trucks, which will be presented in term of the system analysis and design models. Finally, the DSS output information that is the result of running the solid waste management data.

4.1 Mathematic Model

The DSS for the procurement of MSW collection trucks mainly composes three mathematic models namely the Quantity Estimation Model, the Collection Truck Analysis Model and the Linear Programming Model which theirs details are as following:

4.1.1 The Quantity Estimation Model

Following the previous chapter, the Quantity Estimation Model can be obtained by predicting the future population and the future generation rate of the municipal solid waste that have infused a reasonable result of this model. The first prediction, the future population, is following as the exponential model that is a general one of the predicting population due to the concept of urban development described in the third chapter. This prediction model is expressed with the equation below:

$$P_n = P_o \left(1 + r\right)^n$$

Where P_n : numbers of future population

P_o : numbers of present population

r : variant rate of population (percent)

n : term of accounted years

As for the prediction of the future generation rate of municipal solid waste which is the main intention of this part, there are variety of related factors that make it difficult to predict. In this research it was presumed that the economic factor, namely the GDP value, was possibly related with the solid waste generation rate in the linear form. So, the GDP data and the collected municipal waste volume data of Bangkok since B.E. 2528 – 2539, as shown in table 3-1and table 3-2, was analyzed using the Linear Regression of SPSS Program to find out their relation. If there is a relationship between them, the model of the future generation rate prediction will be formed in this general form.

$$Y_i = \beta_0 + \beta_1 X_i$$

This analysis was based on the following assumption:

H_0 : there is not relationship between the generation rate of collected municipal waste per capita per day and the GDP average per capita. Or $\beta_1 = 0$.

H_1 : there is relationship between the generation rate of collected municipal waste per capita per day and the GDP average per capita. Or $\beta_1 \neq 0$.

Additionally, the assumption of the linear form of their relationship on a graph about intersecting at y-axis is following this.

H_0 : y value of a graph line equals zero when x value equals zero. Or $H_0 : \beta_0 = 0$.

H_1 :y value of a graph line does not equal zero when x value equals zero. Or $H_1 : \beta_0 \neq 0$.

From running the SPSS program, its output issues an ANOVA table and a Coefficients table as show in table 4-1 and table 4-2. An ANOVA table presents F value equaled 134.986 that is compared with F value of F-Test as follow this:

$F = 133.328 > F_{1,11,0.95} = 4.84$

Table 4-1 An ANOVA table of running the SPSS program

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	0.635	1	0.635	133.328	0.000(a)
	Residual	0.048	10	0.005		
	Total	0.682	11			

Table 4-2 A Coefficients table of running the SPSS program

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.060	0.078		0.772	0.458
	GDP	2.430E-05	0.000	0.964	11.547	0.000

This output indicates that this statistical analysis accepts H_1 of the first assumption or there is relationship between the generation rate of collected municipal waste per capita per day and the GDP average per capita ($\beta_1 \neq 0$). Also same description in a Coefficients table, a significance of GDP is 0.000 is less than level of t-test's significance (0.05) that indicates H_1 of the first assumption be accepted. For the last assumption is described by a significance of constant in a Coefficients table. Its value is .458 is more than level of t-test's significance, so H_0 is accepted or $\beta_0 = 0$. The model of future generation rate prediction is then formed as follow this.

$$W = \left(2.43 \times 10^{-5}\right) GDP \qquad \text{(Eq. 4.1.1 – 1)}$$

Where W is the generation rate of municipal waste per capita per day.

GDP is the Gross Province Product per capita per year

4.1.2 The Calculation Model for Estimating Numbers of Collection Truck

The calculation models of collection truck number form The Bangkok Solid Waste Management Study in Thailand by Japan International Cooperation Agency (JICA), namely equation 3.1.2-5 and 3.1.2-6, are referred in this research. However, some parts of this model, equation 3.1.2-5, is applied to supporting an existing data. From equation 3.1.2-1, just only transport time in equation 3.1.2-3 and unload time in equation 3.1.2-4 is inserted into it. Therefore, the models are applied as below.

$$T = Tc + Th + Td + To \qquad \text{(Eq. 3.1.2 – 1)}$$

$$\left(T - To\right) = Tc + Th + Td$$

From $$Th = \frac{Q}{q} \times t_h \qquad \text{(Eq. 3.1.2 – 3)}$$

And $$Td = \frac{t_d}{q} \times Q \qquad \text{(Eq. 3.1.2 – 4)}$$

$$\left(T - To\right) = Tc + \frac{Q}{q} \times t_h + \frac{t_d}{q} \times Q \qquad \text{(Eq. 4.1.2 – 1)}$$

$$\left(T - To\right) - Tc = \frac{Q}{q} \times \left(t_h + t_d\right) \quad \text{or} \quad Te - Tc = \frac{Q}{q} \times \left(t_h + t_d\right) \qquad \text{(Eq. 4.1.2 – 2)}$$

$$Q = q \times \frac{\left(Te - Tc\right)}{\left(t_d + t_c\right)} \qquad \text{(Eq. 4.1.2 – 3)}$$

However both of these equations 3.1.2 – 5 and 4.1.2 –3 are included into the DSS for the procurement of MSW collection trucks. In addition, a calculation of collection truck number in this research is based on supposing that collection efficiency of BMA is stable for the period of planning.

4.1.3 The Linear Programming Model

The general form of the Linear Programming Model composes two parts; an objective function part and a constraint part. The objective function will state a goal of problem solving in the real world. Whereas the constraint part identifying some restrictions of problem solutions. This research will light up the problems of BMA's solid waste collection and then created the objective function and constraints as showing below.

4.1.3.1 The Objection Function

According to the problem of municipal waste's increasing volume, BMA need a good plan for collecting those waste. Under condition of utilizing the old collection trucks, of which using over seven years, results in the high maintenance cost. For this reason, BMA must provide some new collection trucks for supporting an increasing volume of municipal waste and replacing some old trucks. However, BMA has a limited budget to purchase all new ones. Hence, renting collection trucks from private sector is one choice to this solution, which is stated in the title of solid waste management plan in Bangkok Development Plan Letter 6. Nonetheless, in an economic view there is a cost-benefit differential between the trucks renting and purchasing. On the one hand, truck renting is considered high capital cost but saving the maintenance cost. On the other hand, purchasing is considered worthwhile for long term utilizing but causing high maintenance cost and having a high chance for repairing once using in a long period of time. Therefore, the question to this problem is what the appropriate numbers of collection trucks for renting and purchasing are. Besides, the goal of this problem solution is the minimization of collection cost, namely investment cost and operation cost, that should be under the maximization of collection efficiency. This goal can be accomplished by the following objection function:

$$MIN : \sum_{i=1}^{n} C_i \ X_i + H_i \ Y_i$$

Where X is truck numbers for purchasing.

Y is truck numbers for renting.

C is operation cost and capital cost of truck caused by the purchased truck per bath per ton, which can be calculated by equation below:

C =[(Salary + Fuels Cost + Maintenance Cost) * (365* Volume Load per day of purchasing truck)] + Price of truck
Collection Volume per year

H is operation cost caused by the rental truck per bath per ton which can be calculated by following equation :

H =[(Salary + Fuels Cost) * (365* Volume Load per day of rental truck)] + rental of truck
Collection Volume per year

i is type of truck.

4.1.3.2 The Constraints

Under limited situation of BMA, there are some restrictions and conditions, such as a limited budget, an adequate number of trucks, saving cost and so on, to be considered in this research. As a result of studying on the BMA' solid waste collection researches and the recommendation of the officer in change's, the constraints of collection plan can be defined and expressed in five equations as below:

The first constraint is on the total loads of all purchased trucks and rental trucks should more than the maximum waste volume to be estimated increase. This constraint assign that all trucks for purchasing and renting must have adequate capacity of loading waste for handling the increase volume of municipal waste. Hence, the first constraint can be described as below:

$$\sum_{i=1}\left(A_i\ X_i + B_i\ Y_i\right) \geq G - g \qquad \text{(Eq.4.1.3.2 - 1)}$$

Where A is a volume load of the purchased truck (Ton / Day)

B is a volume load of the rental truck (Ton / Day)

X is a volume load of the rental truck (Ton / Day)

G is a maximum volume of estimated municipal waste for planning's year. (Ton / Year)

g is a present volume of municipal waste or a municipal waste volume of planning's previous year. (Ton / Year)

i is type of collection truck.

The second constraint relates total numbers of the purchased trucks and the rental trucks to the numbers of the required truck, which is the outcome of the calculation model of collection truck number in total from an analysis based on the actual collection efficiency. In order that the future collection efficiency will not be lower than the existing one, the former number thus should not be greater than the latter number. Accordingly, the second constraint can be expressed below:

$$\sum_{i=1}^{n}\left(X_i + Y_i\right) \leq N - Z \qquad \text{(Eq.4.1.3.2 - 2)}$$

Where N is maximum numbers of estimated collection truck.

Z is present numbers of collection truck or truck numbers of planning's previous year.

The third constraint is on the ratio of collection truck number of each collection truck type, which should not be less than the present ratio of collection truck number of each type. Due to the fact that, the specifying used type of collection truck is depended on the location of the district areas, consequently, it is difficult to estimate numbers of each type of the collection truck. Therefore, it is reasonable to use the existent number of each type. Thus, the third constraint can be expressed as follows:

$$\frac{(X_i + Y_i)}{N - Z} \geq \frac{n_i}{Z} \qquad \text{(Eq.4.1.3.2 – 3)}$$

Where N is maximum numbers of estimated collection truck.

Z is present numbers of collection truck or truck numbers of planning's previous year.

n is present truck numbers of each truck type.

i is type of collection truck.

The fourth one is a consideration on the investment and maintenance cost of the purchased trucks and the rental truck which bases on a long-term worthwhile. Although, use of the rental trucks can save maintenance cost in the long term, it generates higher investment cost than the purchasing trucks. Thus, the improvement of utilizing the rental trucks could be in creasing numbers of trip for loading waste rather than purchasing trucks that would result in lower investment cost in average. Therefore, in long term worthwhile consideration, the length of truck utilization that should be limited to seven years. This constraint will consider on the investment cost per trip of the purchased trucks and the rental trucks. It is expected that the total cost of the purchased one should not be more than the rental one. This constraint is expressed as below:

$$\sum_{i=1}^{n} \frac{O \cdot R_i \cdot Y_i}{t * w} \geq \sum_{i=1}^{n} \left(\frac{I_i + O \cdot M_i}{T * W} \right) X_i \qquad \text{(Eq.4.1.3.2 – 4)}$$

Where O is the length of the collection truck utilization. (7 Year)

R is average rental cost of collection truck. (Bath/year)

t is trip number of rental truck's loading waste per day.

w is average workdays of rental truck per year.

I is price of collection truck.(Bath)

M is maintenance cost of collection truck (Bath)

T is average workdays of purchased truck per year.

W is average workdays of purchased truck per year.

i is type of collection truck.

The last constraint is the limitation of budgets for renting and purchasing. Total cost of renting and purchasing truck should be less than the limited budget, which is expressed as the following equation.

$$\sum_{i=1}^{n}\left(I_i\ X_i + R_i\ Y_i\right) \leq V \qquad \text{(Eq.4.1.3.2 – 5)}$$

Where I is price of collection truck.(Bath)

R is rental cost of collection truck. (Bath / Year)

V is a limited budget. (Bath / Year)

From the objective function and constraints above, the Linear Programming for this research could be expressed as:

$$MIN : \sum_{i=1}^{n} C_i\ X_i + H_i\ Y_i$$

Subject to; $\sum_{i=1}\left(A_i\ X_i + B_i\ Y_i\right) \geq G - g$

$$\sum_{i=1}^{n}\left(X_i + Y_i\right) \leq N - Z$$

$$\frac{\left(X_i - Y_i\right)}{N + Z} \geq n_i$$

$$\sum_{i=1}^{n}\frac{O \cdot R_i \cdot Y_i}{t * w} \geq \sum_{i=1}^{n}\left(\frac{I_i + O \cdot M_i}{T * W}\right) X_i$$

$$\sum_{i=1}^{n}\left(I_i\ X_i + R_i\ Y_i\right) \leq V$$

4.2 System analysis and design

4.2.1 Process Modeling

According to the study on the solid waste management system by the Technical and Planning Division (TPD), there are four stakeholders that have connection with namely:

(1) Executive of BMA, a decision maker in BMA's policy, who needs information to support his/her decision-making. Usually, TPD will report the monthly information on waste management, as well as, supporting the technical data and other information as ask for.

(2) District Offices, an actual practical unit, will submit the month report on waste collection data. This data notify TPD of all collection cost data.

(3) Public Service Division, this division's responsibility is for supporting district offices for collection truck management. Main data reported to TPD is the collection truck data including record of truck allocation, maintenance etc.,

(4) Solid Waste Disposal Division that is responsibility for disposed of all collected waste. Daily collected waste volume data from the transfer-stations, which are under this division, will forward the daily data on collected waste volume via Internet. This data will be uploaded to the transaction database and summarized in monthly report.

The data flow and data process of this study can be presented in the Data Flow Diagram as show in figure 4-1, figure 4-2 and figure 4-3

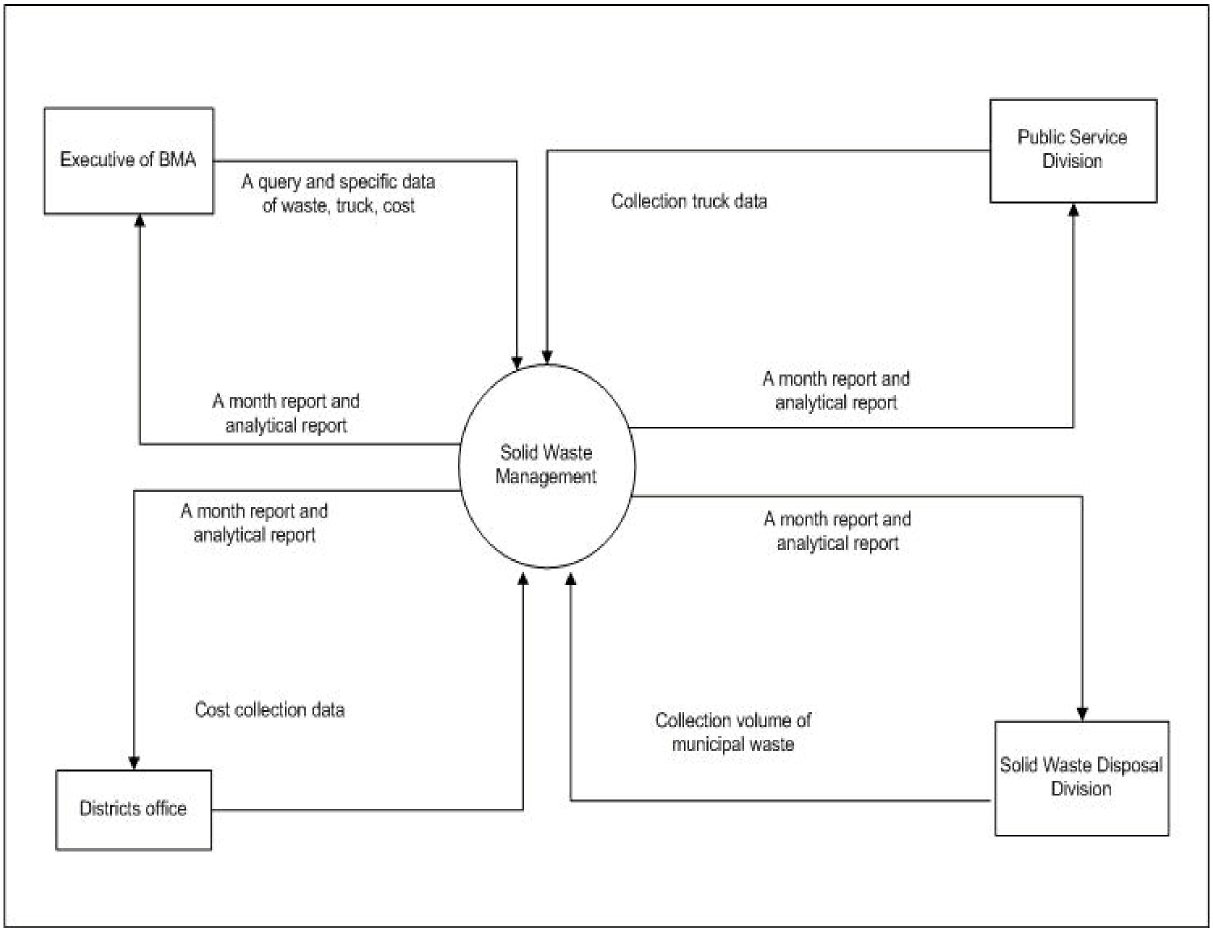

Figure 4-1 Context Diagram of Solid Waste Management System

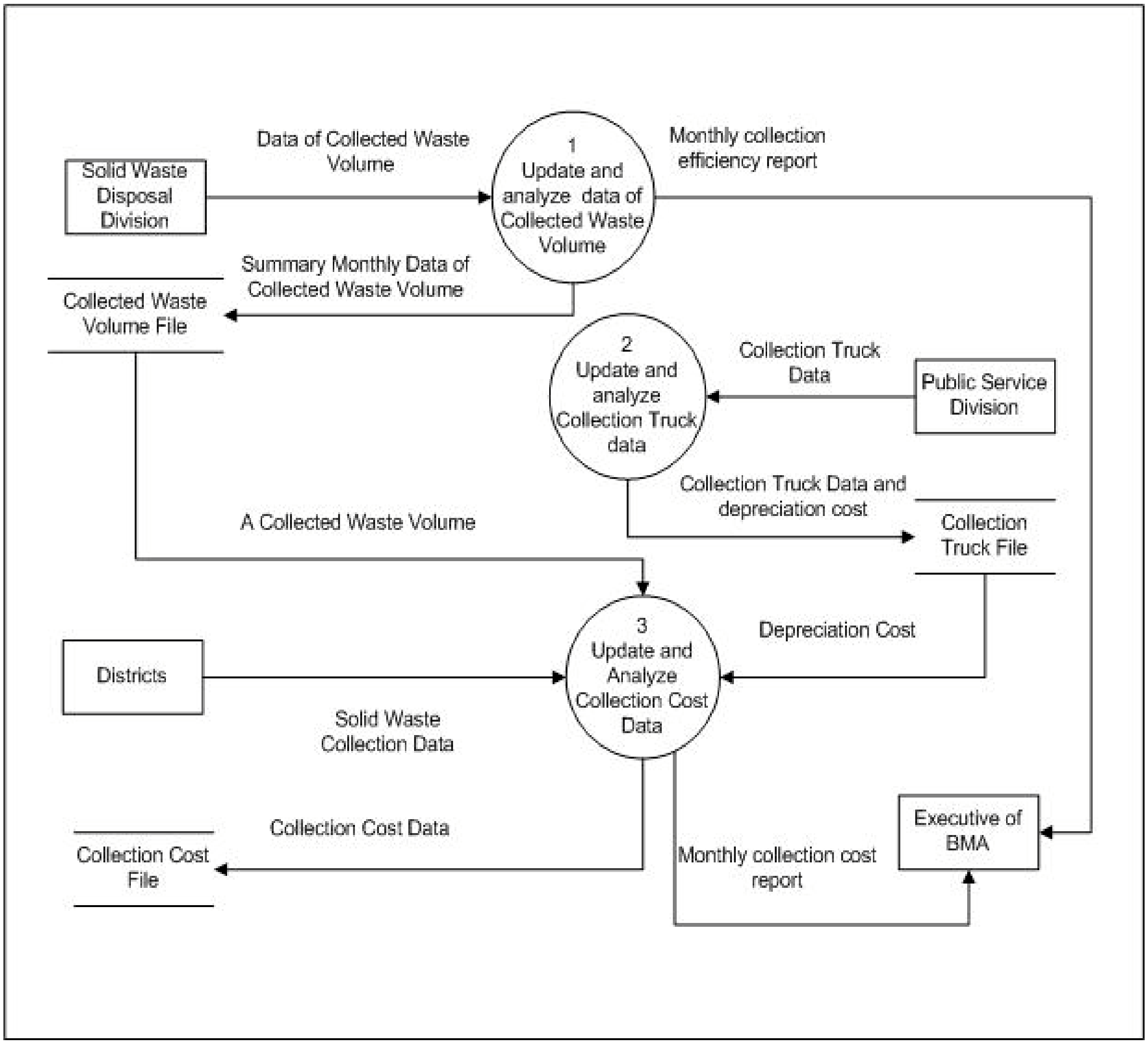

Figure 4-2 Level 0 Data Flow Diagram of Solid Waste Management System

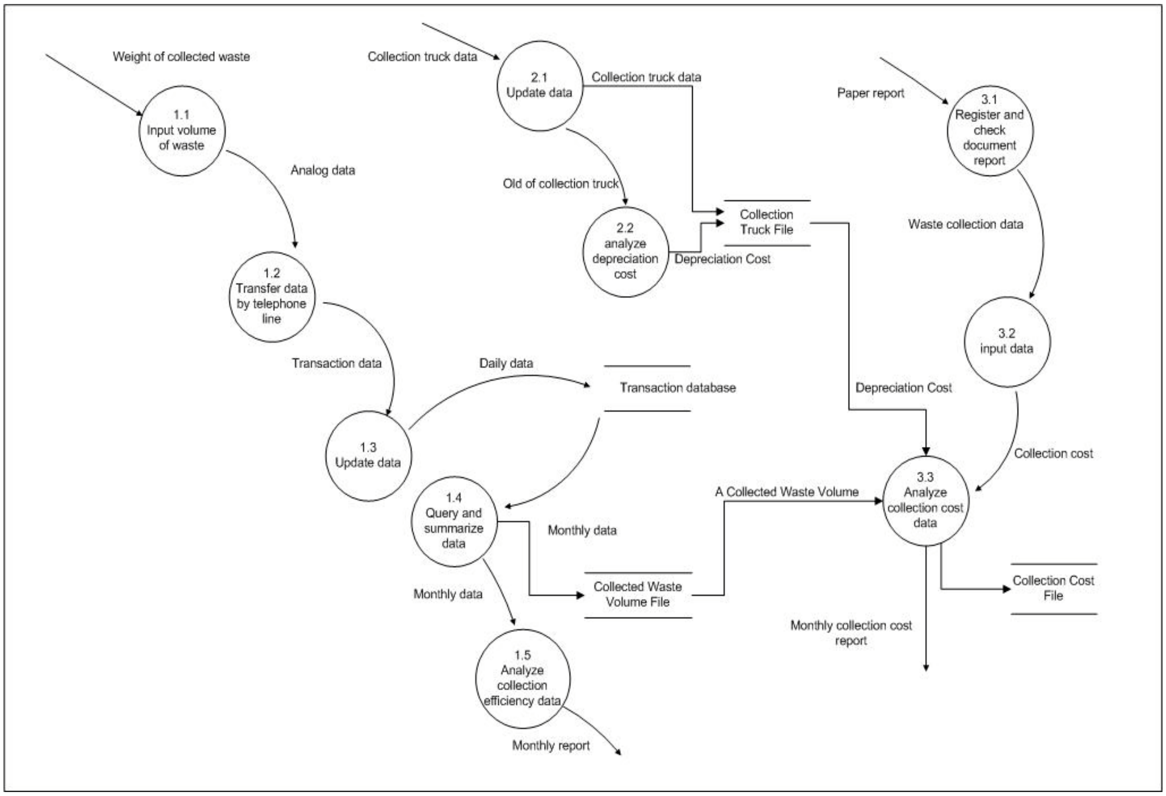

Figure 4-3 Level 1 Data Flow Diagram of Solid Waste Management System

4.2.2 Database Design

In order to get conceptual view of Solid Waste Management data, this research studied the data format and a related report of the TPD to identify relationship between them. This relationship is presented in ER-Diagram as show in figure 4-4. This diagram is then converted into table of Access Database.

4.2.3 User Interface Design

By using Visual Basin Program, user interfaces are created to be a user-friendly which has 7 main forms including:

(1) The login form, this form is created for system security.

(2) The main form which is a parent form of all other form on this system

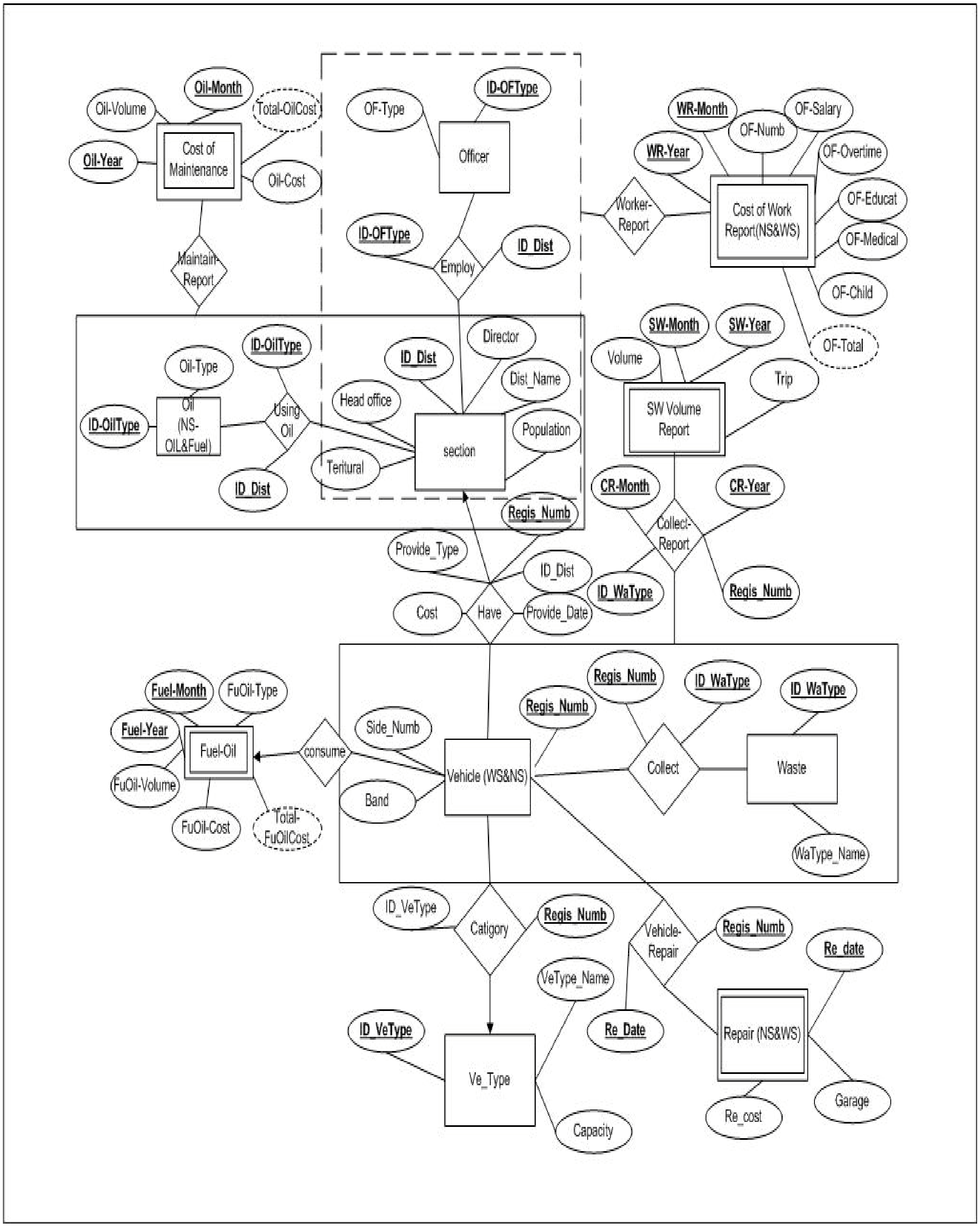

Figure 4-4 ER-Diagram of Solid Waste Management Database

(3) The Zone-district database form, which has three sub-forms to be selected, i.e. zone form, district form and each of one can invoke report form.

(4) The waste collection database form which has three sub-forms to be selected, i.e. waste volume form, collection truck form and depreciation form, which each of one can invoke report form.

(5) The analysis form of waste volume estimation; this form has three forms that display orderly in accordance with system process namely the estimating population form, the estimating waste volume form and the calculating collection number form. After finishing process of this form, the program will continue on next process of the analysis form of the collection truck providing by Linear programming

(6) The analysis form of collection truck providing by Linear Programming which has only one form, the solution form, to display analysis output. This solution form also display on the report form.

(7) The help form, which is composed nineteen text files to be selected for displaying help document.

For the sequence of display of those forms are described in figure 4-5, as well as, their look are illustrated in appendix A.

4.2.4 Constructing the DSS for the procurement of MSW collection trucks

This Decision Support System is principally composed two parts, i.e. database and analysis program, which are linked up by modules of Visual Basic Program. As mention in database design, Access Program is used for construct the database. As for the analysis program has three sub-parts namely the quantity estimation analysis, the collection truck numbers and the optimal numbers analysis of the purchased truck and the rental truck by Linear Program method. The first and second one are processed by connection of Visual Basic Program and Excel Program. For the last one is processed by Visual Basic Program and Lindo API Program, which is a program module to analyze the Linear Programming problem. After the process of program finished, it output will be saved as Excel file in order that the user can retrieve information in next time. The connection of these three parts, as well as passing and processing data, is described by Structure chart as present in figure 4-6 to figure 4-10. For their coded program are presented in appendix B of this thesis report.

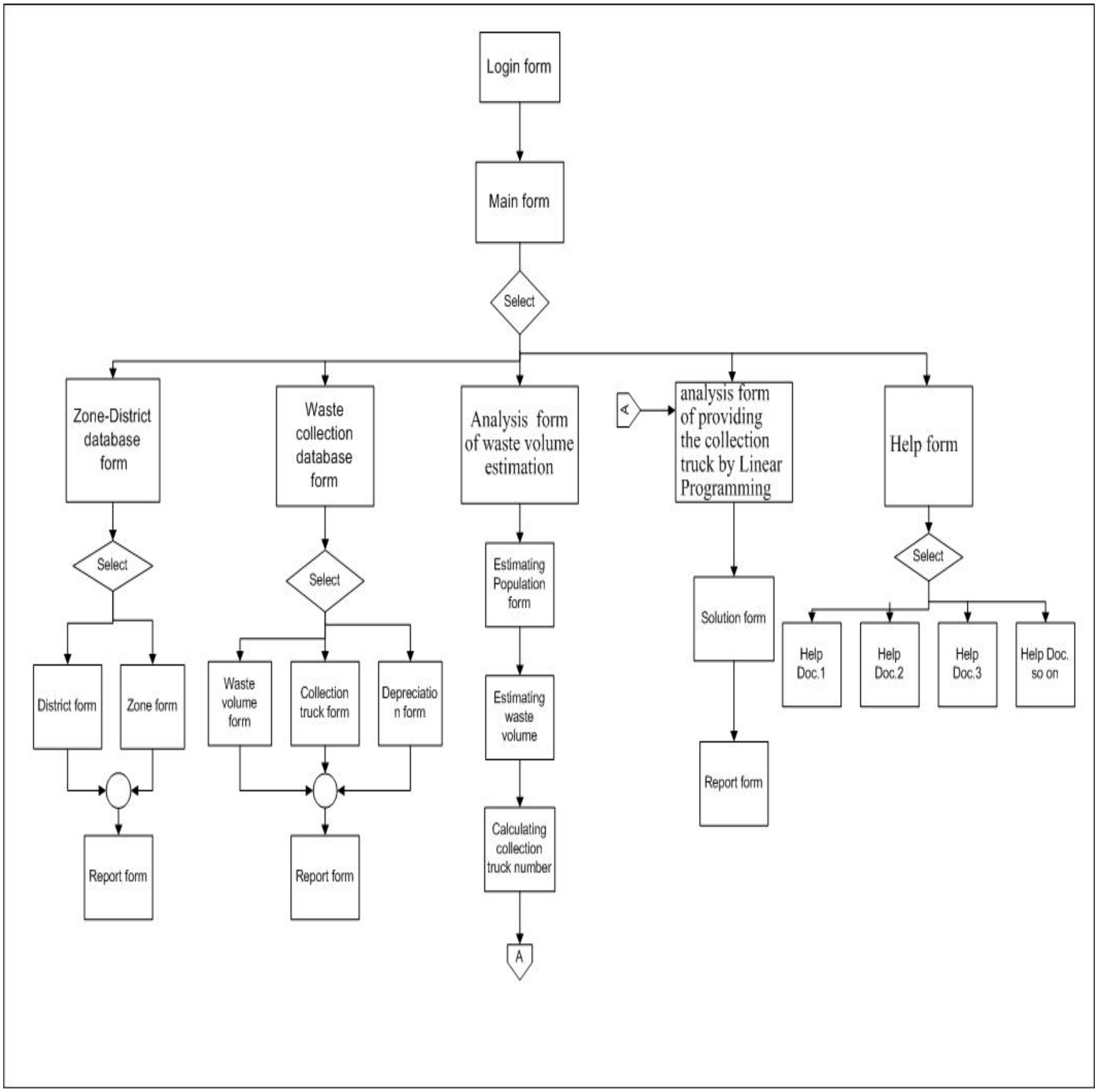

Figure 4-5 Dialogue diagram for the DSS for the procurement of MSW collection trucks

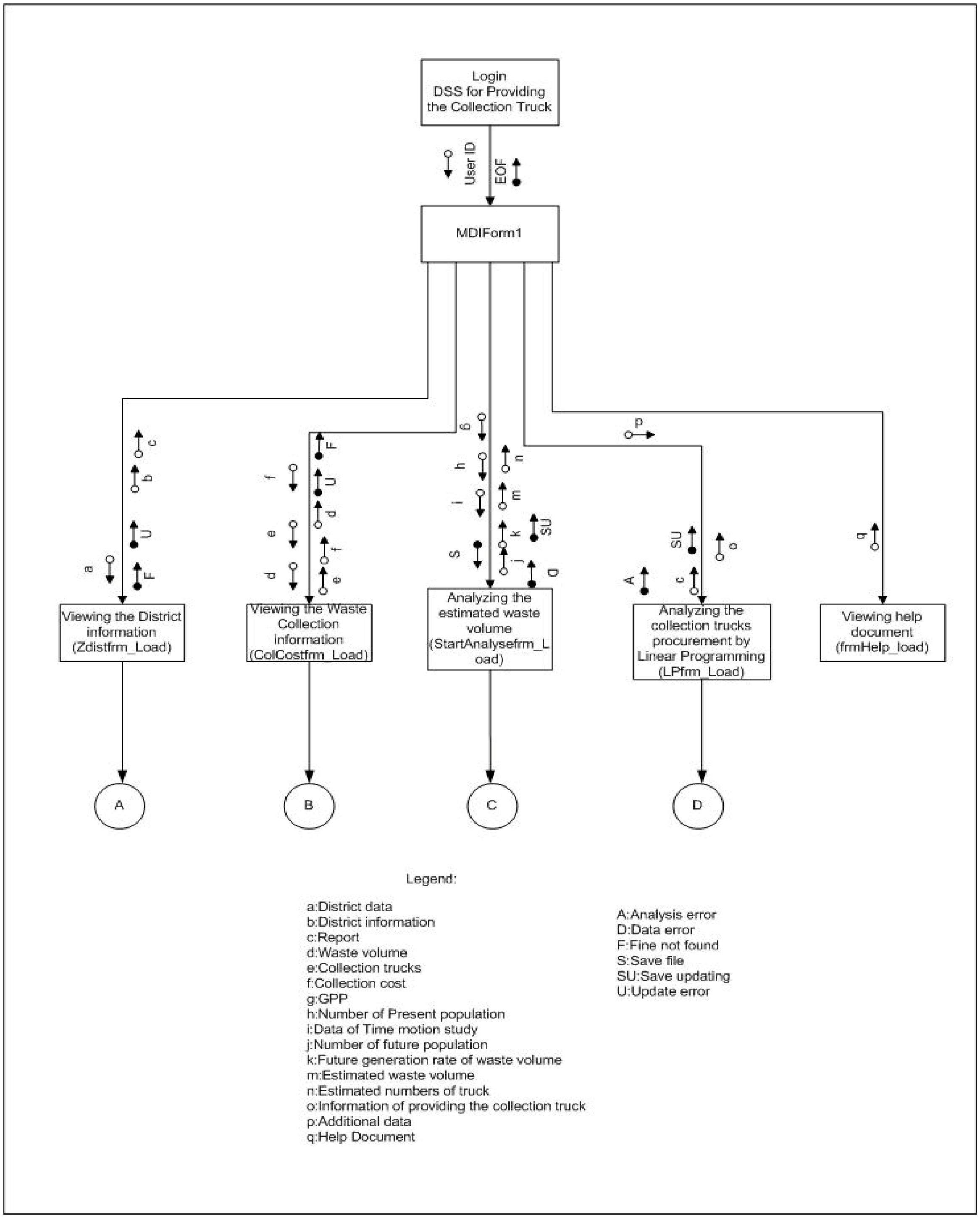

Figure 4-6 Top-Level Structure chart of DSS for the procurement of MSW collection trucks

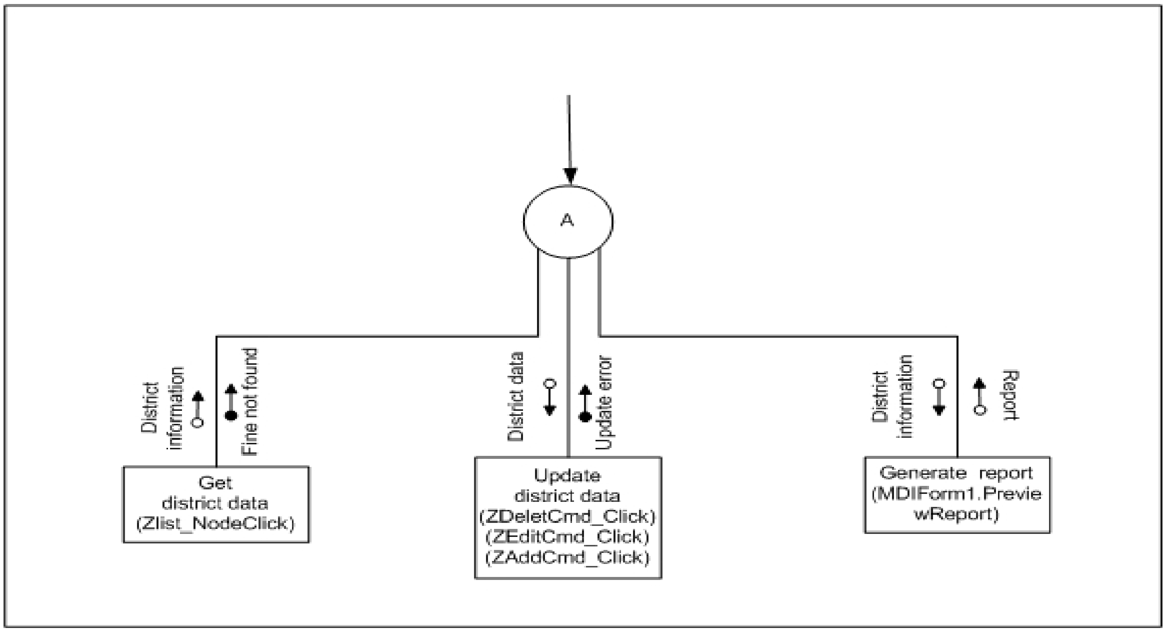

Figure 4-7 Structure chart for Viewing the District Information section of system

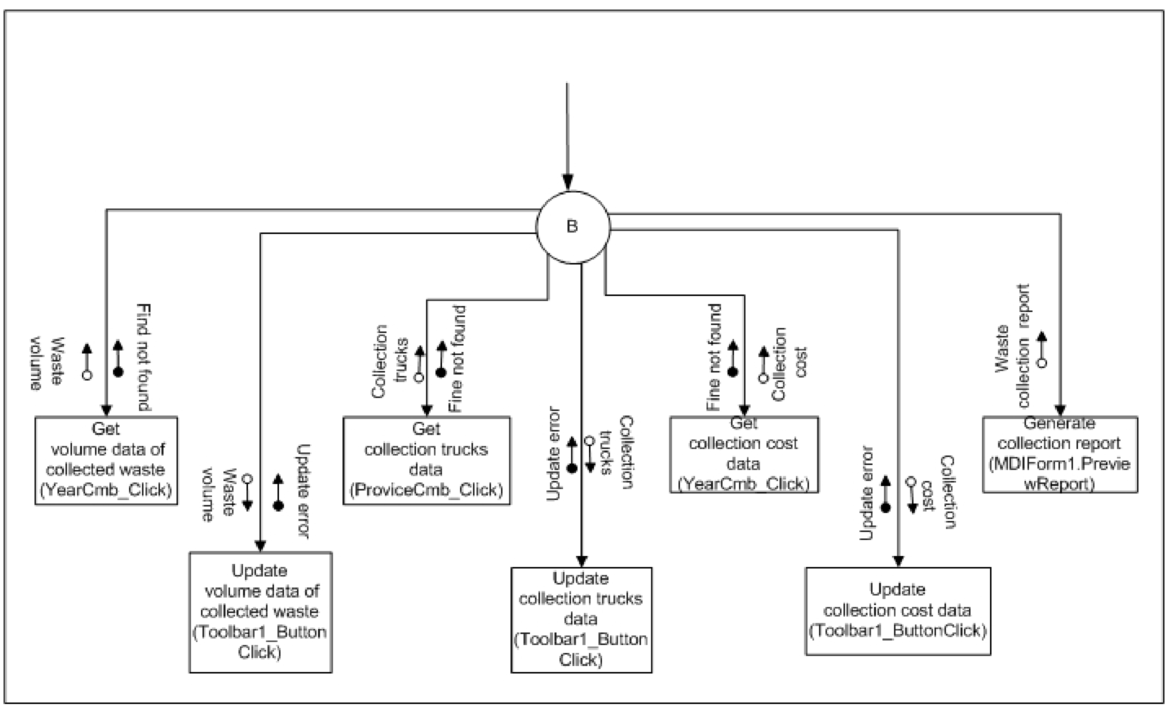

Figure 4-8 Structure chart for Viewing the Collection Information section of system

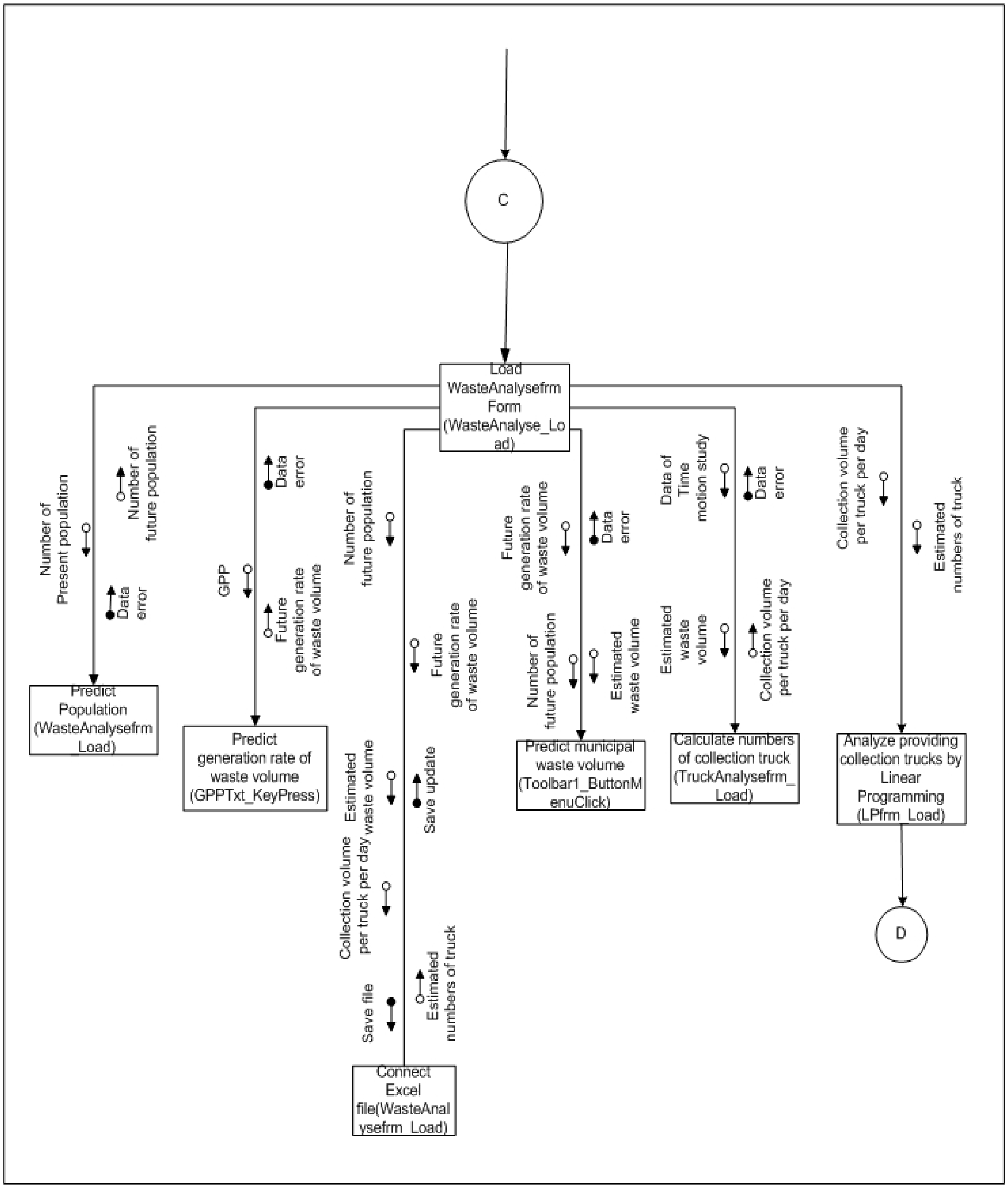

Figure 4-9 Structure chart for Analyzing the Estimated Waste Volume of system

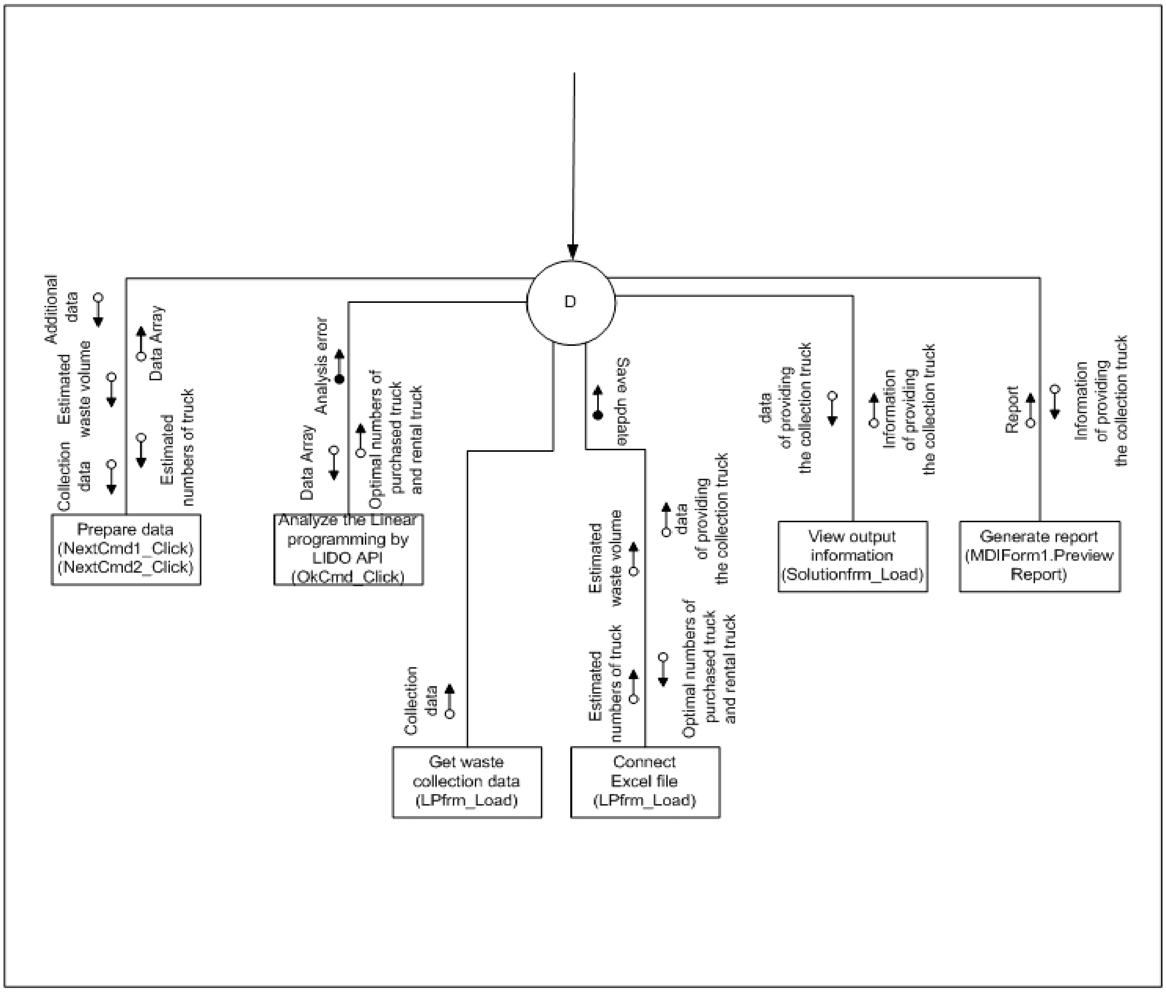

Figure 4-10 Structure chart for Analyzing the Collection Truck Procurement by Linear Programming method of system.

4.3 Analyzing the Optimal Numbers of Purchasing and Renting Collection Truck of BMA

Based on the solid waste collection data in B.E. 2546, BMA had 2,313 collection trucks in 50 district offices and could handle municipal waste about 9,000 ton per day. However, more than 50 percent of those trucks are over 7 year old ones which will deteriorate efficiency. In order to cope with the increasing waste in the future, BMA thus had launched out a project for renting 230 compactor trucks with a capacity of 5 tons from the private sector in B.E. 2547 and would expand subsequently the project for 3 more fleets, i.e. another 202 compactor trucks with the same capacity together with 152 smaller ones of 2 tons and 142 container trucks of 4 tons in the next year. These information were used for assuming the input data along with other related secondary data as presented in appendix C. All these data were inputted into the analysis program of DSS for the procurement of MSW collection trucks to produce the output for supporting the solid waste collection plan as per following details

4.3.1 Future Quantity Estimation of Municipal Waste

From the existing population data and estimated GDP data, the analysis program of DSS for the procurement of MSW collection trucks will automatically estimated the future quantity for next five years as show in table 4-3. The output of this process illustrates trend in increasing of BMA's municipal waste volume in B.E. 2548 – 2552 are 10412.76,11228.22, 12033.20, 12902.79 and 13829.73 ton per day, respectively.

Table 4-3 Future volumes of BMA's municipal waste were estimated by analysis program of DSS for the procurement of MSW collection trucks.

Budget Year	Generation Rate of Municipal Waste (Kg/Cap)	Population (Capita)	Estimated Volume of Municipal waste (Ton/Day)
2548	1.76	5903053.00	10412.76
2549	1.88	5962083.00	11228.22
2550	2.00	6021704.00	12033.20
2551	2.12	6081921.00	12902.79
2552	2.25	6142740.00	13829.73

4.3.2 Estimating Numbers of Required Collection Truck

The former output of analysis program together with the time motion data were input in the second process of program to analyze numbers of required collection truck for managing with those estimated waste. The information of this process was presented in table 4-4

Table 4-4 Numbers of required collection truck was estimated by analysis program of DSS for the procurement of MSW collection trucks.

Budget Year	Estimated Volume of Municipal waste (Ton/Day)	Collection Efficiency (Ton/Trip)	Numbers of Required Collection Truck (Unit)
2548	10412.76	6	1822
2549	11228.22	6	1964
2550	12033.20	6	2105
2551	12902.79	6	2257
2552	13829.73	6	2420

4.3.3 Analyzing the Optimal Numbers of Purchasing and Renting Collection Truck

This process was the last stage of analysis program that informed the user about the optimal numbers of the collection truck that should be purchased and rented in each year of the plan period. The outputs of the former process and the collection data from waste collection database including with the other related data were used for finding out the solution by Linear Programming program. The answer of this process as show in table 4-5, table 4-6, table 4-7 and table 4-8.

Table 4-5 The output information about analyzing the optimal numbers of purchasing and renting collection truck of BMA

Total collection cost of utilizing the purchased trucks and the rental trucks during periods of plan's time. (Bath)		1,979,056,882.35			
Numbers of Truck(Unit)\Year	**1**	**2**	**3**	**4**	**5**
The 4 ton Container Trucks by purchasing	7	50	42	24	36
The 5 ton Compactor Trucks by purchasing	2	185	185	159	133
The 2 ton Compactor Trucks by purchasing	166	0	0	0	0
The 4 ton Container Trucks by rent	2	0	0	0	0
The 5 ton Compactor Trucks by rent	97	179	174	141	129
The 2 ton Compactor Trucks by rent	0	0	0	0	0
Total numbers of the provided truck	274	414	401	324	298
Exist numbers of Collection Truck	1,548	1,374	1,412	1,553	1,538
Total numbers of present truck and provided truck	1,822	1,788	1,813	1,877	1,836
The estimated numbers of collection truck	1,822	1,964	2,105	2,257	2,420
Collection cost (Bath)\Year					
The 4 ton Container Trucks by purchasing	8,987,068.61	64,193,347.22	53,922,411.67	30,812,806.67	46,219,210.00
The 5 ton Compactor Trucks by purchasing	3,363,603.45	311,133,319.40	311,133,319.40	267,406,474.51	223,679,629.62
The 2 ton Compactor Trucks by purchasing	141,292,445.66	-	-	-	-
The 4 ton Container Trucks by rent	1,255,205.74	-	-	-	-
The 5 ton Compactor Trucks by rent	69,470,597.11	128,198,318.38	124,617,359.76	100,983,032.91	92,388,732.24
The 2 ton Compactor Trucks by rent	-	-	-	-	-
Total collection cost of utilizing the purchased trucks and the rental trucks	224,368,920.57	503,524,985.00	489,673,090.83	399,202,314.09	362,287,571.86

Table 4-6 The output information about analyzing the optimal numbers of purchasing and renting collection truck of BMA (continued)

Collection cost (Bath)\Year	1	2	3	4	5
The collected solid waste volumes (tons/day)\Year					
The 4 ton Container Trucks by purchasing	33.98	242.70	203.87	116.50	174.75
The 5 ton Compactor Trucks by purchasing	12.31	1,138.84	1,138.84	978.78	818.73
The 2 ton Compactor Trucks by purchasing	496.79	-	-	-	-
The 4 ton Container Trucks by rent	12.73	-	-	-	-
The 5 ton Compactor Trucks by rent	857.17	1,581.79	1,537.60	1,245.99	1,139.95
The 2 ton Compactor Trucks by rent	-	-	-	-	-
Total volumes of collected solid waste of the purchased trucks and the rental trucks	1,412.98	2,963.33	2,880.31	2,341.27	2,133.42
The exist volumes of collected municipal waste in plan year	10,412.76	11,228.22	12,033.20	12,902.79	13,829.73
Amount of the collected solid waste volume	9,000	10,412.76	11,228.22	12,033.2	12,902.79
The estimated future volume of solid waste	10,412.98	13,376.09	14,108.53	14,374.47	15,036.21
Investment and maintenance cost of the provided truck during seven years (Bath/Trip)					
The 4 ton Container Trucks by purchasing	6,777.008487	48,407.20348	40,662.05092	23,235.45767	34,853.1865
The 5 ton Compactor Trucks by purchasing	2,254.744578	208,563.8735	208,563.8735	179,252.194	149,940.5145
The 2 ton Compactor Trucks by purchasing	132391.0177	0	0	0	0
Total investment and maintenance cost of the purchased trucks	141,422.7708	256,971.077	249,225.9244	202,487.6517	184,793.701
Investment and maintenance cost of the provided truck during seven years (Bath/Trip)					
The 4 ton Container Trucks by rent	2,506.85	-	-	-	-
The 5 ton Compactor Trucks by rent	138,609.04	255,783.70	248,638.90	201,483.25	184,335.74
The 2 ton Compactor Trucks by rent	-	-	-	-	-
Total Investment cost of the rental trucks	141,115.89	255,783.70	248,638.90	201,483.25	184,335.74

Table 4-7 The output information about analyzing the optimal numbers of purchasing and renting collection truck of BMA (continued)

The investment cost of the provide trucks (Bath\Year)	**1**	**2**	**3**	**4**	**5**
The 4 ton Container Trucks by purchasing	8,970,500.00	64,075,000.00	53,823,000.00	30,756,000.00	46,134,000.00
The 5 ton Compactor Trucks by purchasing	3,357,600.00	310,578,000.00	310,578,000.00	266,929,200.00	223,280,400.00
The 2 ton Compactor Trucks by purchasing	141,050,200.00	-	-	-	-
The 4 ton Container Trucks by rent	1,249,600.00	-	-	-	-
The 5 ton Compactor Trucks by rent	69,093,100.00	127,501,700.00	123,940,200.00	100,434,300.00	91,886,700.00
The 2 ton Compactor Trucks by rent	-	-	-	-	-
Amount of investment cost (Bath)	223,721,000.00	502,154,700.00	488,341,200.00	398,119,500.00	361,301,100.00
Budgets (Bath)	594,966,000.00	594,966,000.00	594,966,000.00	596,596,100.00	576,938,700.00
Collection data	**Capacity (Ton/Day)**	**Operate cost (Bath//Ton)**	**Investment cost (Bath/Unit)**	**Repair cost (Bath/Unit)**	**% Of decreasing the old truck**
The 4 ton Container Trucks by purchasing	4.85	487.62	1,281,500.00	37,704.98	50
The 5 ton Compactor Trucks by purchasing	6.16	487.62	1,678,800.00	84,693.80	60
The 2 ton Compactor Trucks by purchasing	2.99	487.62	849,700.00	87,768.42	50
The 4 ton Container Trucks by rent	6.36	440.40	624,800.00	-	-
The 5 ton Compactor Trucks by rent	8.84	440.40	712,300.00	-	-
The 2 ton Compactor Trucks by rent	3.18	440.40	525,400.00	-	-
Numbers of an old truck (over than 7 old truck) (Unit)\year	**1**	**2**	**3**	**4**	**5**
The 4 ton Container Trucks by purchasing	160	119	59	29	15
The 5 ton Compactor Trucks by purchasing	1005	408	242	102	307
The 2 ton Compactor Trucks by purchasing	165	88	44	22	11

Table 4-8 The output information about analyzing the optimal numbers of purchasing and renting collection truck of BMA (continued)

Numbers of decreased old truck (Unit)\year	1	2	3	4	5
The 4 ton Container Trucks by purchasing	80	60	30	14	8
The 5 ton Compactor Trucks by purchasing	603	245	145	61	184
The 2 ton Compactor Trucks by purchasing	82	44	22	11	6

The output of this process purposes that BMA should assign the budget of 223,721,000.00, 502,154,700.00, 488,341,200.00, 398,119,500.00 and 361,301,100.00 Bath in B.E. 2548 – 2552 to procure 274, 414, 401, 324 and 298 collection trucks respectively. For the optimal numbers of truck should be purchased and rented in each year as presented in table 4-5, which their total collection cost were estimated at 1,979,056,882.35 Bath during the period of plan. This estimated collection cost, however, excluded the collection cost of exist collection trucks in each years of plan's period.

4.4 Evaluation

In order to evaluate the efficiency of DSS for the procurement of MSW collection trucks, this research had generated an attitude questionnaire about the system efficiency and the user friendly to question 10 users who were the officers in change of the Technical and Planning Division. The result of this questionnaire, as shown in table 4-6, found that 8 of 10 users evaluate their appreciation for this system not lower than on good level. Most of them evaluated process and report of DSS was suitable and useful for the solid waste management plan on very good level. For user interface, data view and comprehension of the system process was evaluated on good level by 7 of 10 users. All of users accepted that database and data queries of DSS are according to the objective of the solid waste management plan. In overview of DSS, the users accepted that DSS for the procurement of MSW collection trucks could be a tool to support the waste management plan due to its output informed a useful data for collection trucks management planning.

Table 4-9 The result of evaluation about the system efficiency and the user friendly of the DSS for the procurement of MSW collection trucks by 10 users.

Question	Very Good	Good	Fairly Good	Poor	Bad
User interfaces are a user friendly	3	7	-	-	-
Data views are met user requirement.	3	7	-	-	-
Reports are appropriated and met user requirement.	5	5	-	-	-
System process is clear	3	7	-	-	-
Efficiency of system process.	2	6	2	-	-
Database and data queries are according to objective of solid waste management plan.	5	5	-	-	-
System process and report is suitable and useful for solid waste management plan	7	3	-	-	-
Output of analysis program informs a useful data for planning collection trucks management.	4	6	-	-	-
DSS for the procurement of MSW collection trucks can be a tool to support waste management plan.	4	6	-	-	-

CHAPTER V
CONCLUSION AND DISCUSSION

Subsequently to the program test, this chapter concludes and discusses its output in two parts namely, the solution to BMA's waste collection problem by running the analysis program and the efficiency of DSS for the Collection Truck Provision.

5.1 Solution to BMA's Waste Collection Problem

There are three stages of the analysis process to be concluded and discussed as follows:

5.1.1 Estimation of Municipal Waste Quantity in Future

In order to prove that the output of municipal waste quantity estimation process can be accepted, the quantity of BMA's municipal waste estimated by this program is compared with those done and analyzed by JICA in B.E. 2534 and JBIC in B.E. 2544 respectively as showed in the table 5 –1.

Table 5 – 1 Comparison of BMA's municipal waste estimations by JICA, DSS for the procurement of MSW collection trucks and JBIC

Year	JICA	DSS for the procurement of MSW collection trucks	JBIC
2548	12,920	10,412.76	10,652
2549	13,550	11,228.22	10,891
2550	14,180	12,033.20	11,138
2551	14,800	12,902.79	11,386
2552	15,420	13,829.73	11,643

In the table 5-1, the comparison showed the estimation by DSS for the procurement of MSW collection trucks stood between those by JICA and JBIC. Based on the current volume of BMA's municipal waste at about 9000 tons per day, it is unlikely to go up to 12,920 tons/day in B.E. 2548 as estimated by JICA. As for both the series of figures from JBIC and this research which are more or less at about the same level, there is likelihood. However, in consideration of the higher average growth rate of 8.5% from this research over that of 2.5% from JBIC, the former, which is closer to the BMA's annual municipal waste increase during B.E.2534 – 2539 at a pace of 8.65%, offers flexibility and therefore acceptable for the management plan. This conclusion merely views the quantity estimation of BMA's municipal waste. In practice, reliability of the output depends very much on the accuracy of the data input.

5.1.2 Estimation of the Number of Collection Truck

The result of calculation at this stage shows that BMA should acquire 1,822, 1,964, 2,105, 2,257 and 2,420 collection trucks from B.E. 2548 to 2552 respectively, whereas BMA now has 2313 ones. The significant discrepancy does not derive from any error in the research process but rather the inefficiency of a half of the BMA's fleet being old trucks over 7 years which should be disposed of. If these old trucks are excluded, the rest will be consistent with the estimation from the research.

5.1.3 Analysis on the Optimal Number of Collection Truck to Purchase and Rent

The output of the last stage proposed BMA plan for procurement of collection truck as follows table 5-2.

Furthermore, this output presents the data to support a decision taking which is verifiable, taking into account the aforesaid constraints as earlier determined, in the following manner;

(1) The collection trucks to be procured in accordance with this research's output can cope sequentially with each volume of MSW about 10,143, 11,228, 12,033, 13,788 and 15,139 ton per day from the 1st to 5th year in the plan respectively. These capacities are greater than the estimated volumes of MSW and

therefore meet the requirement of the first constraint condition as per the equation 4.1.3.2-1.

Table 5 – 2 The optimal number of collection trucks to purchase and rent

Category of Truck	**1st Year**	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**
4 ton Container Truck	P 7 units R 2 units	P 50	P 42 units	P 24 units	P 36 units
2 ton Compactor Truck	P 166 units				
5 ton Compactor Truck	P 2 units R 97 units	P 185 units R 179 units	P 185 units R 174 units	P 159 units R 141 units	P 133 units R 129 units

P = Purchase / R = Rent

(2) Each annual number of the trucks from the 1st to 5th year is 1,822, 1,788, 1,813, 1,877 and 1,8361respectively responds to the second constraint on the equation 4.1.3.2-2. However, there is an observation in this respect with regard to the existing number of each category of trucks as determined in the equation 4.1.3.2-3 in each year, which is greater than the estimation in this research. This is an effect from the old trucks used by BMA which caused the runtime error while the program was running Linear Programming analysis. In order to eliminate this factor, the estimated number of each category of trucks was set equal to zero by default and would not affect Linear Programming process.

(3) The total annual investment in and maintenance costs per unit per round of the purchased trucks and rented ones of the plan are provided in the table below.

Table 5 – 3 The total annual investment in and maintenance costs per unit per round of the purchased trucks and rented ones of the plan

Annual Investment plus Maintenance Cost per unit per round (Baht)					
Option	**1st Year**	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**
Purchase	141,422.77	256,971.07	249,225.92	202,487.65	184,793.70
Rent	141,115.89	255,783.70	248,638.90	201,483.25	184,335.74

The above table affirms the fourth constraint in the equation 4.1.3.2-4 which determined higher investment and maintenance cost on the purchased trucks than the rental ones.

(4) The total investment cost of the provided trucks, which is less than the BMA's allocated budget following as per the last constraint of equation 4.1.3.2-5. The output of the Linear Programming analysis suggests that BMA allocate as follow table 5-4. These budgets are not over those based on the last constraint in the equation.

Table 5 – 4 The total investment cost of the provided trucks

	1st Year	2nd Year	3rd Year	4th Year	5th Year
Budget	223,721,000	502,154,700	488,341,200	398,119,500	361,301,100

All the foregoing brings about a conclusion that the solution to BMA's waste collection problem is reliable. However, there are some other factors to also consider as follows;

(I) From a practical viewpoint, the prediction model of population growth in this research is not suitable for a forecast of a longer period than three years. However, since the objective of this research focused on an overview of the collection plan, therefore, a forecast of this related data for planning the procurement of the collection trucks just represented one of the basic inputs.

(II) With regard to the existing number of collection trucks which is more than the plan's estimation, if the net number of trucks calculated after subtracting those over 7 yeas of age had been used, the investment would have been much higher than the allowable budget. This research thereby determined percentage of the old truck exclusion in order that Linear Programming analysis can be processed as realistically as possible.

(III) The volume of collected municipal waste as gathered from the BMA's B.E. 2546 records to be referred to in the plan's first year is rather low, about 7087.12 tons per day, which could possibly cause an error in the analysis. Since BMA was then in the transitional period transforming its manual system into computerized system and there could be some inaccuracy in the data compilation resulting in the lower volume than what actually took place. In order to eliminate this error, the volume of collected municipal waste in the plan's first year was assumed about 9,000 tons per day.

5.2 Efficiency of DSS for the Procurement MSW Collection Trucks

From an evaluation of the system efficiency, while 8 out of 10 users evaluated the questionnaire at acceptable level and thereby accepted this research as pass, the rest regarded the same as fairly good in view of the structure of program which has a connection with not only the excel software for the analysis but also the access software for the data retrieval plus the application of the program module of Lindo API in Linear Programming. The program may take quite some time in processing for an output.

From all the studies made, this research represented one of several ways of using Linear Programming method in finding a solution to the waste management problem. Unlike other researches where either a site selection or finding out the best possible route of waste collection usually was a problem of concern, this one pinpointed the BMA's specific issue on a provision of the optimal number of collection trucks to be purchased and rented based on the collection cost minimization by analyzing objectives and such practical constraints on waste collection plan as several inefficient old trucks which incur very high collection cost, ever increasing municipal waste volume, limited budget and how to minimize the collection cost and translating them into a mathematic model to find out the solutions. This process was included in the information system, called DSS for the procurement of MSW collection trucks in order to serve as a tool for waste management plan for users. This

DSS can also be used as a database for future data maintenances and updates as well as in producing significant output for a waste management plan just in a few minutes' time instead of acquiring knowledge-base information which normally consumes a great deal of time. All in all, output or information from it can assist executives in decision taking on the optimal collection truck provision with the minimal collection cost.

CHAPTER VI
RECOMMENDATION

In order to find out actual solution, this research translated the objectives and key practical restrictions on waste collection plan into the mathematic models and solved the problems by Linear Programming approach. However, the research can not cover some other certain constraints, which are listed below for further consideration.

6.1 Actual collection cost per collection truck which varies from one category to another in terms of driver's wage, fuel, maintenance cost etc. and this can not be ascertained as BMA does not keep the data category-wise. Hence the research can not really have an accurate analysis in this regard.

6.2 Amount of collection cost in the entire planning period in the research is merely an increased cost from purchasing and renting collection trucks. This cost does not include expenses in waste collection of the existing trucks incurred in each year. As the goal of this research is to find out an optimal number of collection trucks to purchase and rent based on minimal collection cost. It will be more useful, if the total cost can also cover the collection cost.

6.3 As this research focuses on macro plan of BMA's waste management, some practical restrictions in operating municipal waste collection are not included in the constraints of Linear Programming model. Those restrictions, which can be analyzed by a micro study on waste collection at the district level, are mentioned hereunder.

6.3.1 Further study on which model in particular suits individual district area considering the utmost efficiency and minimal cost is to be made and included in the future research.

6.3.2 BMA may be bound by its rental collection truck contracts in such ways that its workers may have to change their working hours or perhaps more steps of operation to undergo which may result in increasing collection cost. These hidden costs should be included in the constraints to exactly reflect the real cost of waste collection actually arising from rental trucks.

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APPENDIX

APPENDIX A

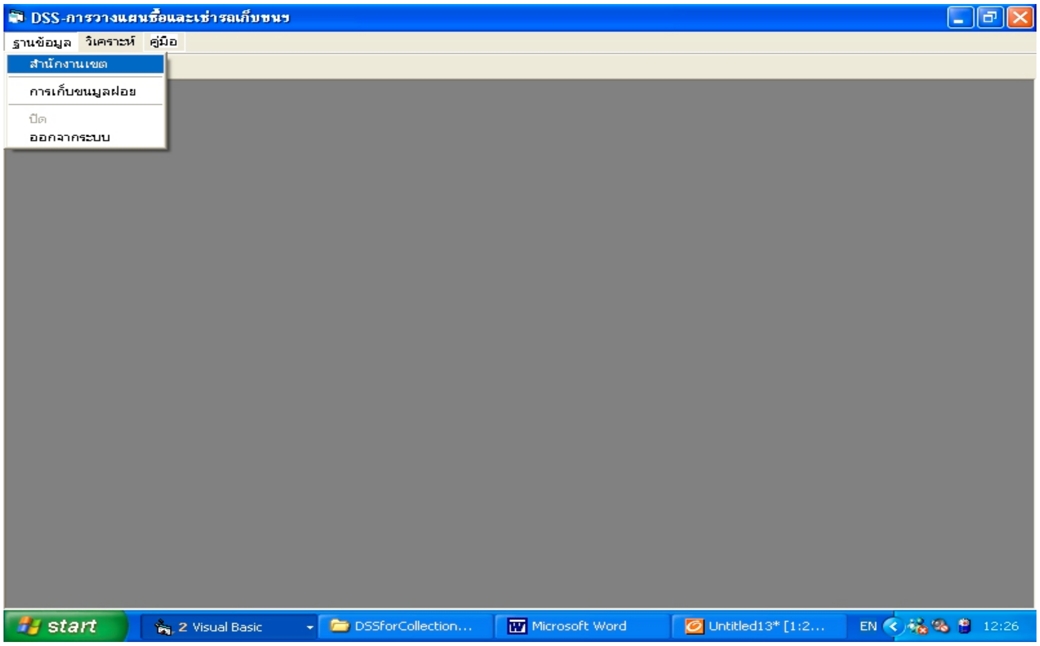

Figure A – 1 Main form of DSS for the procurement of MSW collection trucks

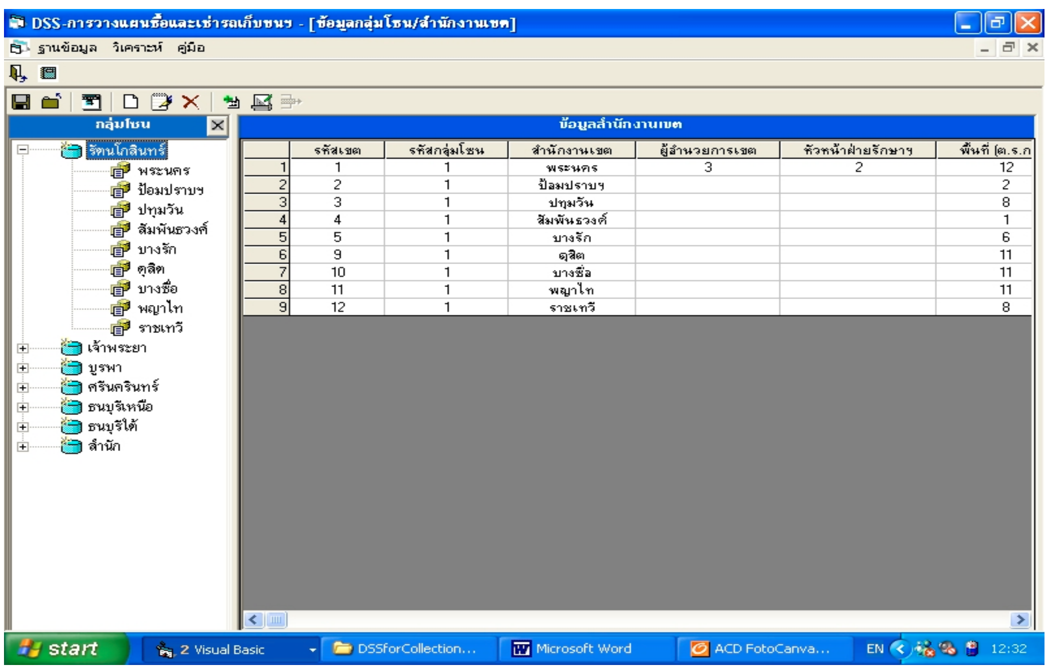

Figure A – 2 Zone Database form of DSS for the procurement of MSW collection trucks

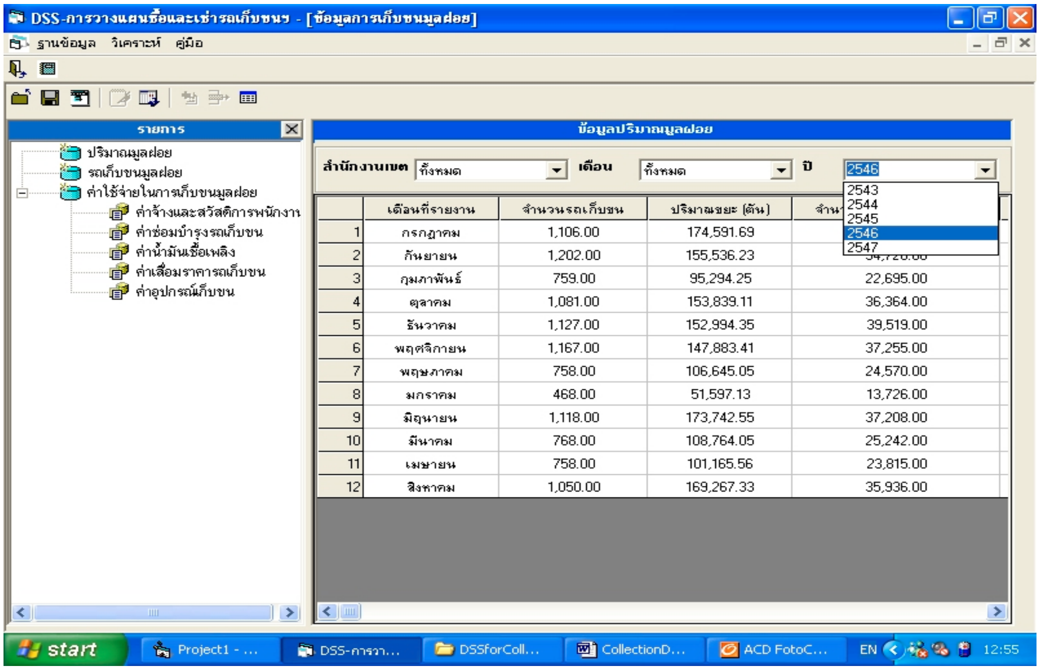

Figure A – 3 Waste Collection Database form of DSS for the procurement of MSW collection trucks

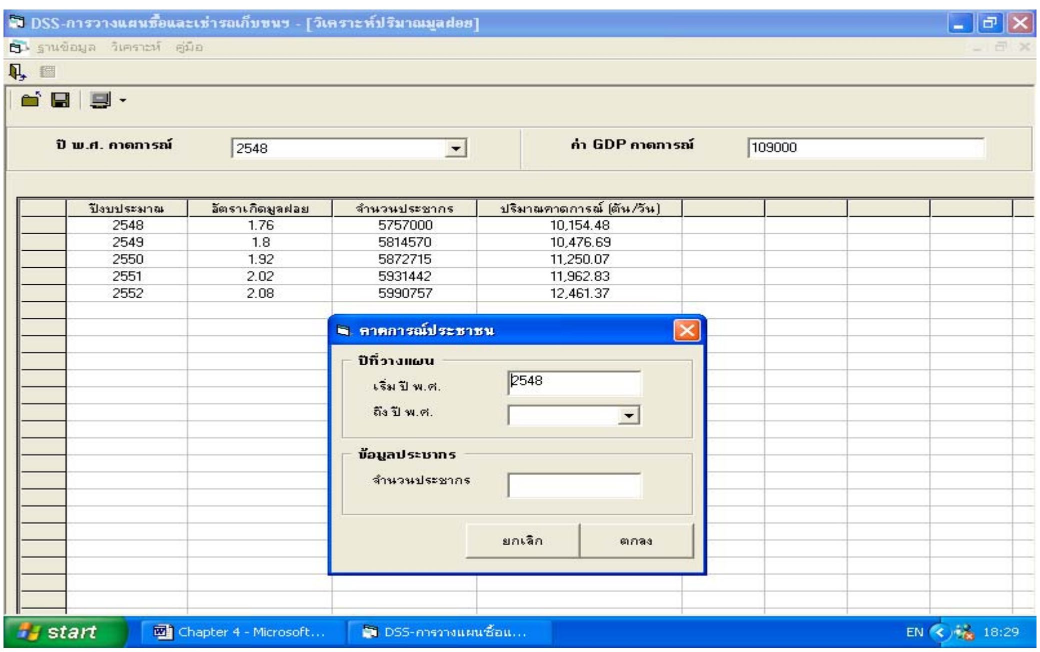

Figure A – 4 Waste Volume Estimation form of DSS for the procurement of MSW collection trucks

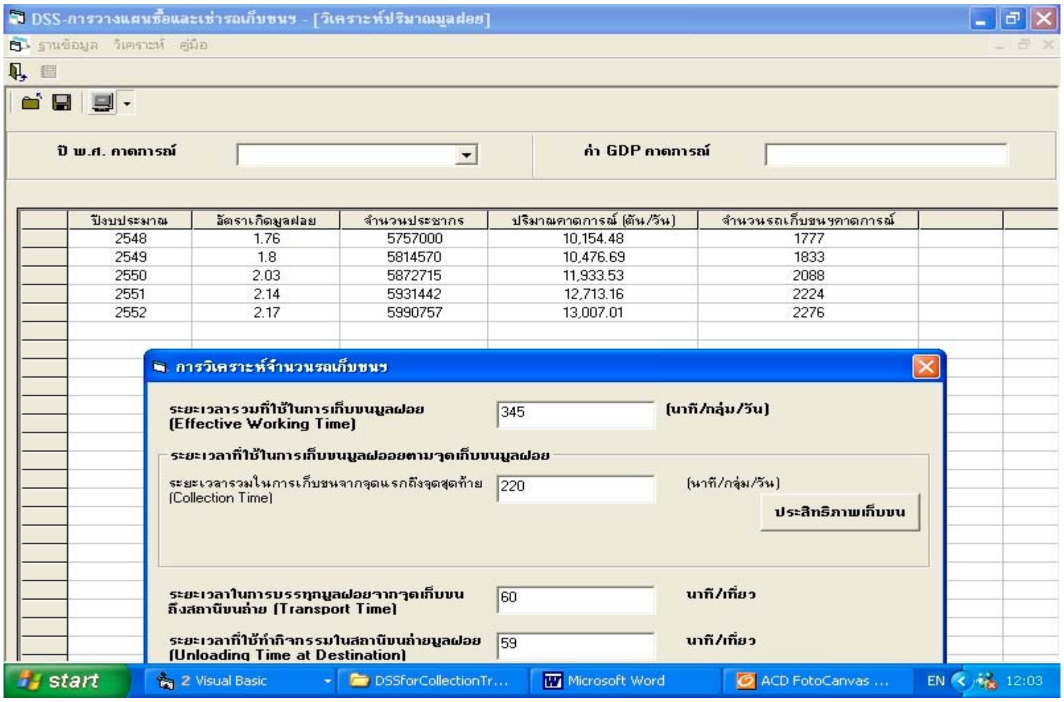

Figure A – 5 Collection Truck Number Estimation form of DSS for the procurement of MSW collection trucks

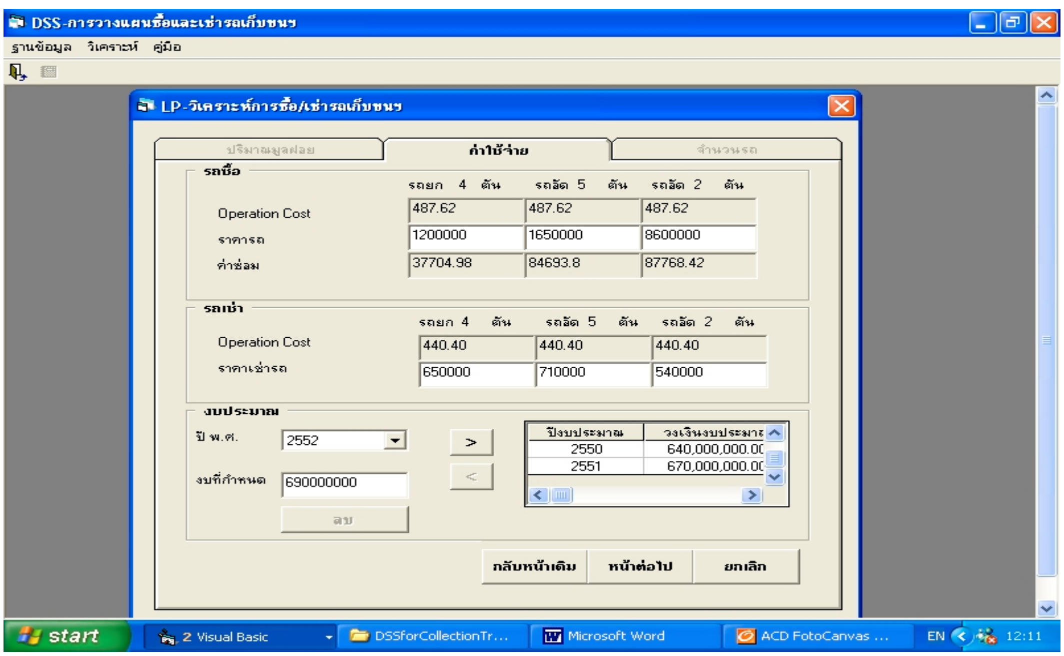

Figure A – 6 Linear Programming Analysis form of DSS for the procurement of MSW collection trucks

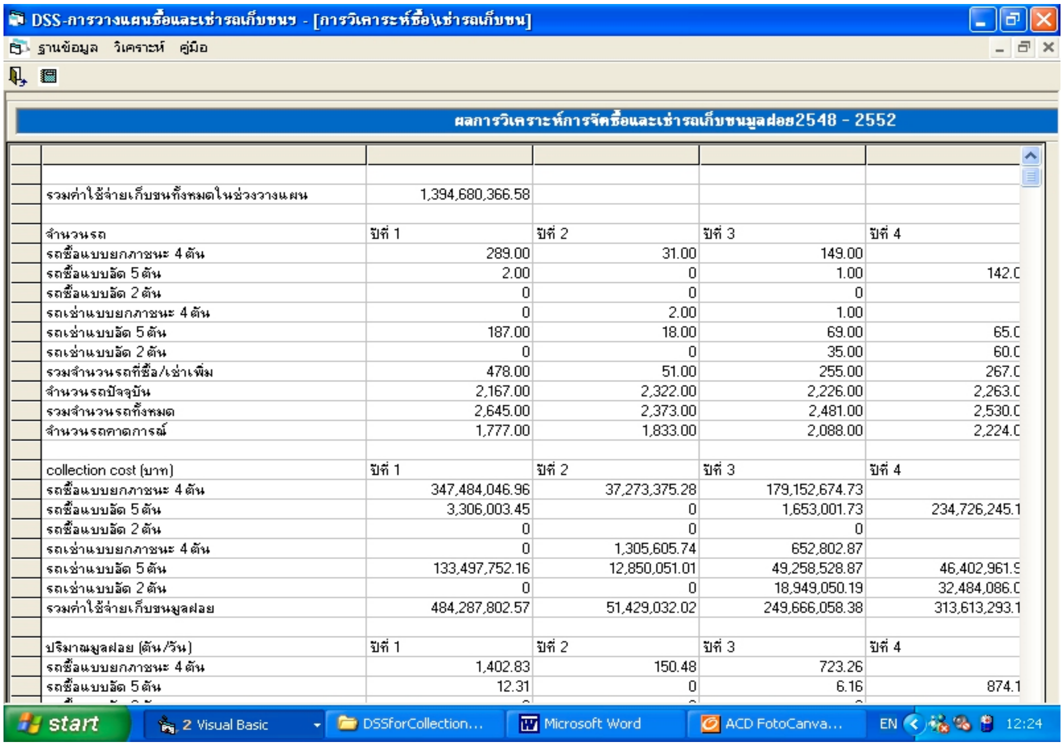

Figure A – 7 Solution form of DSS for the procurement of MSW collection trucks

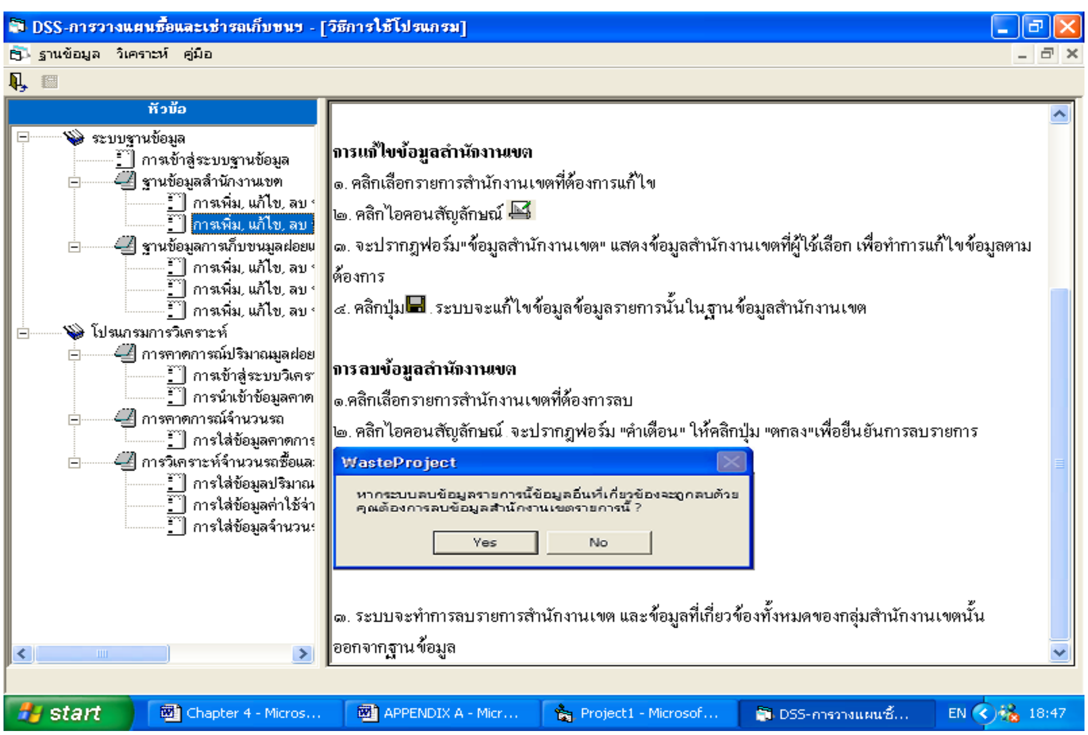

Figure A – 8 Help form of DSS for the procurement of MSW collection trucks

APPENDIX B

Example of connecting Excel and Access Application

```
Public xlApp As Application
Public xlWorkbook As Workbook
Public xlSheet As Worksheet
Public LPSheet As Worksheet
Public FirstYear, LastYear As String
Dim X, Y, Z, t, BudgetY, countYear, TruckY, Turn
Dim AddEditMode As String
Dim CmdClickmode, CmdVolumeAdd, CmdTruckClick As Integer
Dim TruckOptMode As String
Dim g(), a(5), V(), AB(5), Ic(5), CT(5), RequestNumb8(), RequestNumb5(),
RequestNumb2(), turnNumb(2), Turns(3)
Public ConAb As Connection
```

Private Sub Form_Load()

```
Dim VolumeRst As Recordset
Screen.MousePointer = vbHourglass
Call OpenConnection(volumeCon, VolumeRst, "SWVolumePerDay")
Call ndCmbAction(PresentYear, VolumeRst, "SWYear")
Set xlApp = New Excel.Application
If StartLp = 1 Then
   xlApp.Workbooks.Open WasteAnalysefrm.FName
Else
   xlApp.Workbooks.Open App.Path & "\WasteTruckEstimate3.97.xls"
End If
Set xlWorkbook = xlApp.ActiveWorkbook
Set xlSheet = xlWorkbook.Worksheets(1)
xlSheet.Cells(9, 1).Formula = "=Count(a2:a8)"
Call InputDataGrid(1, 4, "###,###.00", VolumeGrid, xlSheet.Cells(9, 1))
VolumeCmd1.Enabled = False
VolumeCmd2.Enabled = False
Call LockEdit(PredictYear, PredictVolume)
```

```
'------------------------------------------
'TabScrip of "ค่าใช้จ่าย"
Dim OperationCostRst As Recordset
Dim RepairCostRst8 As Recordset
Dim RepairCostRst5 As Recordset
Dim RepairCostRst As Recordset
Dim OperCostRst As Recordset
Dim By
Set OperationCostRst = volumeCon.Execute("select CostPerTon from
OperatCostofPur")
OperationCostRst.MoveLast
Dim i
For i = 0 To 2
    OpCost(i).Text = Format(OperationCostRst!CostPerTon, "###,###.00")
     RepairCost(i).Text = GetRepairCost(8 - (3 * i))
Next i
Set OperCostRst = volumeCon.Execute("select CostPerTon from OperatCostofRent")
OperCostRst.MoveLast
Dim R
For R = 3 To 5
   OpCost(R).Text = Format(OperCostRst!CostPerTon, "###,###.00")
Next R
BudgetGrid.FormatString = "^" & "ปีงบประมาณ" & Space(8) & "|^" & "วงเงินงบประมาณ" &
Space(8)
For By = 1 To VolumeGrid.Rows - 1
        BudgetYear.AddItem VolumeGrid.TextMatrix(By, 0)
Next By
BudgetYear.AddItem " "
BudgetCmd2.Enabled = False
BudgetCmd1.Enabled = False
'----------------------------------
'TapScrip of "จำนวนรถ"
TruckYearCmb.Visible = False
Call InputDataGrid(1, 5, "##,###", TruckGrid, xlSheet.Cells(9, 1))
Call LockEdit(TruckYear, TruckNumbTxt)
TurckOpt1_Click
TruckCmd1.Enabled = False
```

```
TruckCmd2.Enabled = False
With SSTab1
    .TabEnabled(1) = False
     .TabEnabled(2) = False
.Tab = 0
End With
NextCmd1.Enabled = False
DeleteCmd.Enabled = False
Screen.MousePointer = vbDefault
MDIForm1.WasteEstimation.Enabled = False
MDIForm1.PurchaseAndRent.Enabled = False
End Sub
'------------ closing connection of Excel Application

Private Sub Form_QueryUnload(Cancel As Integer, UnloadMode As Integer)
If StartLp = 2 Then
xlWorkbook.Close SaveChanges:=False
StartLp = 0
xlApp.Quit
Set xlApp = Nothing
End If
End Sub
```

Example of calling Lindo API modul

```
Call CheckErr(pEnv, nErr)
  '>>> Step 1 <<<:  Create a LINDO environment.
pEnv = LScreateEnv(nErr, LicenseKey)
If (nErr > 0) Then
   MsgBox ("Unable to create environment.")
   End
End If

'>>> Step 2 <<< create a model in the environment
Dim pMod As Long
pMod = LScreateModel(pEnv, nErr)
Call CheckErr(pEnv, nErr)
```

```
'>>> Step 3 <<< construct the model
'number of variables
Dim nVars As Long
nVars = 6

'number of constraints
Dim nRows As Long
nRows = 7

'direction of objective
Dim nDir As Long
nDir = LS_MIN

'objective constant term
Dim dObjConst As Double
dObjConst = 0

'objective coefficients
ReDim dObjCoef(nVars) As Double
For i = 0 To 2 'nVars - 1
  dObjCoef(i) = a(i)
  Debug.Print a(i)
Next
For i = 3 To 5 'nVars - 1
  dObjCoef(i) = a(i)
  Debug.Print a(i)
Next

'get the staffing needs for the model's right-hand sides
ReDim dB(nRows) As Double
dB(0) = g(Year - 1) '+ DeleteVolume
dB(1) = PredictNumb
dB(2) = LowNumb8
dB(3) = LowNumb5
dB(4) = LowNumb2
dB(5) = 0
dB(6) = V(Year - 1)
```

```
'define the constraint types
Dim cConTypes As String
  cConTypes = "GLGGGLL"

'the number of nonzero coefficients
Dim nNZ As Long
nNZ = 30

'the array of column start indices
ReDim nBegCol(nVars + 1) As Long
For i = 0 To nVars
    nBegCol(i) = 5 * i
Next

'the nonzero coefficients
ReDim dA(nNZ) As Double
ReDim nrowx(nNZ) As Long
k = 0
For l = 0 To 1
For i = 0 To 2
  For j = 0 To 4
If j < 2 Then
    nrowx(k) = j
Else
 If j = 2 Then
    nrowx(k) = j + i
 Else
    nrowx(k) = j + 2
  End If
End If
    k = k + 1
  Next j
Next i
Next l
```

```
'-- construck array data of coefficence constraint
For i = 0 To 2   ' coefficient of the 5th constraint ( investment and maintenance of
                        pruchasing truck)
    CT(i) = (Ic(i) + (CVar(RepairCost(i).Text) * 7)) / (WorkDay(i) * Trip(i) * 7) * (-1)
                                                                            '/trip per day* work day per year
      LPSheet.Cells(i + 59, 7) = CT(i) * (-1)
Next i
For i = 3 To 5      ' coefficient of the 5th constraint ( investment and maintenance of
rental truck)
     CT(i) = (Ic(i) * 7) / (WorkDay(i) * Trip(i) * 7)
      LPSheet.Cells(i + 59, 7) = CT(i)
Next I

'-- incluse all coefficient constrain in to one array data
Dim X(4, 5)
For i = 0 To 5
    X(0, i) = AB(i)
    X(1, i) = 1
    X(2, i) = 1
    X(3, i) = CT(i)
    X(4, i) = Ic(i)
Next I

'-- load coefficient constraint
k = 0
For j = 0 To 5
For i = 0 To 4
    dA(k) = X(i, j)
k = k + 1
Next i
Next j

'load the problem
nErr = LSloadLPData(pMod, nRows, nVars, nDir, _
 dObjConst, dObjCoef(0), dB(0), cConTypes, nNZ, _
 nBegCol(0), ByVal 0, dA(0), nrowx(0), ByVal 0, _
 ByVal 0)
```

```
Call CheckErr(pEnv, nErr)

'integer restrictions on the variables
Dim cVarType As String
For i = 1 To nVars
   cVarType = cVarType & "I"
Next
nErr = LSloadVarType(pMod, cVarType)
Call CheckErr(pEnv, nErr)

'>>> Step 4 <<< solve the model
nErr = LSsolveMIP(pMod, ByVal 0)
Call CheckErr(pEnv, nErr)

'>>> Step 5 <<< retrieve the solution
ReDim dX(nVars) As Double
Dim dObj As Double
Dim dSlacks(7) As Double
nErr = LSgetInfo(pMod, LS_DINFO_MIP_OBJ, dObj)
Call CheckErr(pEnv, nErr)
nErr = LSgetMIPPrimalSolution(pMod, dX(0))
Call CheckErr(pEnv, nErr)
nErr = LSgetMIPSlacks(pMod, dSlacks(0))
Call CheckErr(pEnv, nErr)
'post solution in dialog box
For i = 0 To nVars - 1
   Resual = 0
   Resual = dX(i)
   LPSheet.Cells(i + 5, Year + 1) = CInt(Resual)
Next
PurchaseNumb8 = LPSheet.Cells(5, Year + 1)
PurchaseNumb5 = LPSheet.Cells(6, Year + 1)
PurchaseNumb2 = LPSheet.Cells(7, Year + 1)
PurchaseNumb = PurchaseNumb8 + PurchaseNumb5 + PurchaseNumb2
```

```
'>>> Step 6 <<< Delete the LINDO environment
Call LSdeleteEnv(pEnv)
If PurchaseNumb = 0 Then
   GoTo En
End If

En:
Solutionfrm.Show
Unload Me
Exit Sub
ErrHander:
If Err.Number = 6 Then
    Resual = dX(i)
    Resume Next
End If
End Sub
```

APPENDIX C

Table C – 1 Estimation of Thailand’s economic trend in B.E. 2548 – 2552

	2545	2546	2547	2548	2549	2550	2551	2552	เฉลี่ย แผนฯ 9	เฉลี่ยปี 2548 -52
1. ผลิตภัณฑ์มวลรวมภายในประเทศ (%)	5.4	6.8	6.0	6.0	6.0	5.5	5.5	5.3	6.0	5.7
2. ผลิตภัณฑ์มวลรวม (พันล้านบาท) 1/	5,451.9	5,938.9	6,455.6	7,067.6	7,739.0	8,397.6	9,108.0	9,864.0	7,739.0	9,864.0
พันล้านดอลลาร์ สรอ.1/	126.8	143.1	159.4	172.4	188.8	204.8	222.1	240.6	188.8	240.6
3. รายได้ต่อหัว (บาท/ปี) 1/	86,537.4	93,525.7	100,484.1	109,008.9	118,440.4	127,534.0	137,272.6	147,541.1	118,440.4	147,541.1
อัตราการเปลี่ยนแปลง, % 1/	6.1	8.1	7.4	8.5	8.7	7.7	7.6	7.5	8.7	7.5
ดอลลาร์ สรอ./ปี 1/	2,012.3	2,253.6	2,481.1	2,658.8	2,888.8	3,110.6	3,348.1	3,598.6	2,888.8	3,598.6
อัตราการเปลี่ยนแปลง, % 1/	9.8	12.0	10.1	7.2	8.7	7.7	7.6	7.5	8.7	7.5
4. ด้านการใช้จ่าย (%,2531=100)										
4.1 การบริโภค	4.6	5.5	5.9	5.6	5.4	5.3	5.3	4.7	5.4	5.3
- ภาคเอกชน	4.9	6.3	5.6	5.6	5.5	5.5	5.0	5.0	5.6	5.3
- ภาครัฐบาล	2.5	1.1	8.0	6.5	5.0	4.0	4.0	3.0	4.6	4.5
4.2 การลงทุน	6.5	11.7	13.8	14.5	13.8	11.4	8.9	8.7	12.1	11.4
- ภาคเอกชน	13.2	17.9	16.0	16.0	15.0	13.0	10.0	10.0	15.6	12.8
- ภาครัฐ	-5.8	-2.3	7.0	8.0	10.0	10.0	8.0	4.0	3.4	8.0
5. อัตราเงินเฟ้อ										
- ดัชนีราคาผู้บริโภค	0.7	1.8	2.7	3.0	3.0	2.6	2.5	2.5	2.2	2.7
- GDP deflator	0.7	2.0	2.7	3.5	3.5	3.0	3.0	3.0	2.5	3.2
6. การค้าระหว่างประเทศ										
6.1 การส่งออก (พันล้านบาท)	2,837.7	3,246.3	3,843.5	4,552.4	5,166.9	5,761.1	6,308.4	6,876.2	3,929.3	5,733.0
อัตราเพิ่มของมูลค่า (%)	1.1	14.4	18.4	18.4	13.5	11.5	9.5	9.0	13.2	12.4
การส่งออก (พันล้านดอลลาร์สรอ.)	66.1	78.4	94.9	111.0	126.0	140.5	153.9	167.7	95.3	139.8
อัตราเพิ่มของมูลค่า (%)	4.6	18.6	21.0	17.0	13.5	11.5	9.5	9.0	14.9	12.1
อัตราเพิ่มของปริมาณ (%)	12.2	8.8	6.0	6.0	6.0	5.5	5.5	5.0	7.8	5.6
6.2 การนำเข้า (พันล้านบาท)	2,720.0	3,071.9	3,774.6	4,593	5,328	6,074	6,742	7,416	3,898	6,031
อัตราเพิ่มของมูลค่า (%)	0.9	12.9	22.9	21.7	18.0	14.0	11.0	10.0	15.3	14.9
การนำเข้า (พันล้านดอลลาร์ สรอ.)	63.4	74.2	93.2	112.0	130.0	148.1	164.4	180.9	94.6	147.1
อัตราเพิ่มของมูลค่า (%)	4.4	17.0	25.6	20.2	16.0	14.0	11.0	10.0	16.7	14.2
อัตราเพิ่มของปริมาณ (%)	13.1	8.8	13.0	10.2	9.0	8.0	7.0	6.0	10.8	8.0
6.3 ดุลการค้า										
(พันล้านบาท)	117.7	174.4	68.9	-40.7	-161.1	-312.8	-433.6	-540.0	31.8	-297.6
(พันล้านดอลลาร์ สรอ.)	2.7	4.2	1.7	-1.0	-3.9	-7.6	-10.6	-13.2	0.7	-7.3
สัดส่วนต่อ GDP (%)	2.2	2.9	1.1	-0.6	-2.1	-3.7	-4.8	-5.5	0.7	-3.3
6.4 ดุลบริการและเงินโอน										
(พันล้านบาท)	184.0	155.5	175.0	155.0	150.0	165.0	165.0	165.0	163.9	160.0
(พันล้านดอลลาร์ สรอ.)	4.3	3.8	4.3	3.8	3.7	4.0	4.0	4.0	4.0	3.9
6.5 ดุลบัญชีเดินสะพัด										
(พันล้านบาท)	301.7	329.9	243.9	114.3	-11.1	-147.8	-268.6	-375.0	195.7	-137.6
(พันล้านดอลลาร์ สรอ.)	7.0	8.0	6.0	2.8	-0.3	-3.6	-6.6	-9.1	4.7	-3.4
สัดส่วนต่อ GDP (%)	5.5	5.6	3.8	1.6	-0.1	-1.8	-2.9	-3.8	3.3	-1.4
7. อัตราแลกเปลี่ยน (บาท/ดอลลาร์สรอ.) 1/	43.0	41.5	40.5	41.0	41.0	41.0	41.0	41.0	41.0	41.0

Source: Office of the National Economic and Social Development Board

Table C – 2 Data about time motion study of BMA's municipal waste collection

เขต	เวลาที่ใช้ (นาที)				รวมเวลาในการเก็บขน (นาที/เที่ยว)	ปริมาณมูลฝอยที่เก็บขน (ตัน/เที่ยว)
	จุดเริ่มต้น-จุดแรกของการเก็บขน	การเก็บขนจากจุดแรกถึงจุดสุดท้าย	จากจุดสุดท้ายของการเก็บขนถึงสถานีขนถ่าย	สถานีขนถ่ายถึงจุดเก็บรถ		
ปทุมวัน	46	218	82	52	391	4.534
คลองเตย	47	215	72	46	380	5.048
บางกะปิ	36	260	53	80	460	5.4
มีนบุรี	12	267	64	61	415	7.994
บางกอกน้อย	27	187	44	49	307	4.899
เฉลี่ย	33.583	220.167	60.767	59.167	379.500	5.687

Source: The Study Project of Preparing the Plan for Improving the Efficiency of District Solid Waste Management Department of Public Cleansing, Bangkok Metropolitan Administration

แบบประเมินประสิทธิภาพระบบสนับสนุนการตัดสินใจเพื่อการจัดหารถเก็บขนมูลฝอย

ข้อมูลผู้ประเมิน

ชื่อ.______________________________. นามสกุล.______________________________.

ตำแหน่ง.__________________________. หน่วยงาน .____________________________.

1. ความสะดวกและประสิทธิภาพของระบบ

หัวข้อ	ดีมาก	ดี	ปานกลาง	น้อย	ควรปรับปรุง
หน้าจอระบบมีลักษณะเหมาะสม สื่อให้ผู้ใช้เข้าใจได้ง่าย					
รูปแบบหน้าจอและการนำเสนอข้อมูลเหมาะสม และตรงกับความต้องการเพื่อปฏิบัติงาน					
รูปแบบการนำเสนอรายงานมีความเหมาะสม					
ขั้นตอนการทำงานของระบบไม่ซับซ้อน ใช้งานได้ง่าย					
ระบบประมวลผลได้อย่างรวดเร็วและมีประสิทธิภาพ					

2. ความเหมาะสมและประโยชน์ของการใช้ระบบ

หัวข้อ	ดีมาก	ดี	ปานกลาง	น้อย	ควรปรับปรุง
การรวบรวมข้อมูลมีความเหมาะสมและตรงกับวัตถุประสงค์ในการวางแผนจัดการมูลฝอย					
การประมวลผลและจัดทำรายงานของระบบมีความเหมาะสมและเป็นประโยชน์ในการวางแผนจัดการมูลฝอย					
โปรแกรมการวิเคราะห์การจัดซื้อและเช่ารถเก็บขนมีความเหมาะสมและเป็นประโยชน์ในการวางแผนการใช้รถเก็บขนมูลฝอย					
โดยภาพรวมระบบสนับสนุนการตัดสินใจฯ สามารถสนับสนุนการวางแผนการจัดการมูลฝอยและเป็นประโยชน์ในการปฏิบัติงานจัดการมูลฝอย					

หมายเหตุ การให้คะแนนเรียงตามลำดับดังนี้
ดีมาก 5 คะแนน ดี 4 คะแนน ปานกลาง 3 คะแนน น้อย 2 คะแนน ควรปรับปรุง 1 คะแนน

BIOGRAPHY

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