AGGREGATE PLANNING USING TRANSPORTATION MODEL: A CASE STUDY OF BANGKOK METROPOLITAN ADMINISTRATION'S MUNICIPAL SOLID WASTE MANAGEMENT

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ABSTRACT

Title of Dissertation	Aggregate Planning Using Transportation Model: A Case Study of Bangkok Metropolitan Administration's Municipal Solid Waste Management
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This research aimed to apply the Vogel's Approximation Method (VAM) to support a decision making process in municipal waste management of Bangkok Metropolitan Administration (BMA). Specifically, VAM method was used as a simulation tool to optimize the transportation route and cost of the waste management system. This study was a mixed-method research using both qualitative and quantitative approaches. Qualitative techniques was used to study the internal management system of the BMA. Data collection and analysis were used to assess the transportation cost and efficiency.

Currently, the BMA has to handle large amounts of waste at over 8,800 tons/day with a transportation cost of approximately 2,290,490 baht per day or 836,028,949 baht per year. VAM method was used to rearrange the members of each transfer station in order to calculate an optimal transportation routes and costs for the BMA. It was found that the BMA can reduce its transportation to 2,249,664 baht per day, or decreasing from the present cost 14,901,647 baht per year. When a new Ratchavipa sub-station starts its operation, the cost of BMA's municipal waste transportation system will be approximately 2,120,402 baht per day, or decreasing from the present cost 62,082,284.25 per year. VAM method was also used to simulate when Ratchavipa sub-station starts its operation, the cost of BMA's municipal waste transportation system will be approximately 1,943,038 baht per day, or decreasing from the cost by BMA 64,737,762 per year. VAM method was also used to assess the effects of other special events, i.e., Songkran Festival and flooding situations. In addition, VAM method was used to simulate when the recycle and composting rates are increased. From the results of this research, it clearly shows that Vogel's approximation method was a practicable tool that can be used to improve a decision making process of the waste management system.

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ABBREVIATIONS

Abbreviations	Equivalence
BMA	Bangkok Metropolitan Administration
TM	Transportation Model
MSWM	Municipal Solid Waste Management
VAM	Vogel’s Approximation Method

CHAPTER 1

INTRODUCTION

1.1 Introduction and Significance of Research

Municipal solid waste represents a daily problem for Bangkok Metropolitan Administration (BMA) which has to handle large amounts of waste being discharged at over 8,800 tons/day (Bangkok Metropolitan Administration, 2015). BMA is responsible for waste collection, transportation and disposal. The waste collection processes covers fifty districts from which solid waste has to be collected from both residential and commercial sources in each district every day. The collected waste is then transferred to three transfer stations that receive the total amount of solid waste from the collection processes. At the transfer stations, waste is sorted into recycling and composting. Recyclable waste is sold to recycling factories and compostable waste is sent to BMA's composting plant. The remaining waste after these separation processes is sent for final disposal, i.e., landfilling or incineration. The waste handling process mentioned above is a highly complex issue, especially the waste transportation processes, because management has to take many factors into consideration, i.e., economic, technical, legislative and environmental issues. Inadequate information and analysis of the problem can lead to mistakes in decision-making processes. Therefore, it is important for the management to use a robust tool or method in selecting appropriate solutions for given problems. In addition, the BMA was earmarked as a center point of the South-East Asia region when the ASEAN Economic Community (AEC) began on year 2015. One of the effects of important will be increasing population trends in Bangkok. As a result the waste generation rate will definitely be increased due to the increase of population. This raises questions about the year after 2015 and how the decision-makers of the BMA should have an appropriate plan to deal with this situation. In the past, the BMA has also faced special situations that have affected its routine waste management. For example, the political protest in 2016 and the great flood from November 2011 to January 2012. BMA's decision makers should, therefore, have a contingency plan for these kind of special scenarios in the future. As mentioned above, the BMA has to transport waste from 50 districts to three transfer stations and then to the final disposal sites. This is a highly complex situation since the BMA has to deal with a very large number of waste collection vehicles, long distances for waste transfers, and high gasoline prices.

A Transportation Model (TM) is therefore one of the choices to use as a robust tool to help decision-makers with appropriate options to tackle these problems. The specific properties of TM model can be used to simulate potential scenarios that can be used to assist with future waste management planning. The TM model can be set for a cost-benefit function for finding the optimal alternatives. Scenarios or alternatives from the model can help demonstrate a clear picture of future situations. In addition, a set of future values related to population growth, cost dynamics, revenue or future interests, etc. can then be added to the model. Because of its robust characteristics, TM model is then applied for the study of solid waste management in the BMA.

This research aims to define an optimal model for BMA's waste management system with a focus on waste transportation. The model with be beneficial for BMA's decision-makers to help them cope with current waste management problems, as well as possible future scenarios.

The transportation model is a model for the transportation of resources between the various sources. VAM has been successfully applied to various domains, however, but not to the waste management field hitherto. In this research, the Vogel approximation method (VAM) is employed as an optimal technique. The context of BMA's waste management systems is employed as a case study for evaluation of the proposed method with the main objective to minimize the net cost of waste transportation.

1.2 Research Objectives

The main objective of this thesis is to apply the Vogel's Approximation Method (VAM) to support a decision making process in waste management of the

BMA. Specifically, several waste generation scenarios are simulated and compared using the VAM model woth an aim to optimize the transportation route and cost of the system.

1.3 Summary of Research Contributions

The research contributions of this dissertation can be summarized as follows

1) A comprehensive mathematical formulation is developed for the multi-criteria project selection of problems including interdependencies among projects in each period in the planning horizon.

2) An applied evolutionary algorithm is used for planning for the future situation by developing for a multicriteria project selection and future situation under several constraints, including budget constraints and the interdependency of the projects. In this algorithm, Vogel's approximation method (VAM) a well-known transportation model is used with possible future scenarios. This procedure is explored and enhanced in order to improve the algorithm performance for analysis.

3) In this thesis, an application was developed to aid the Bangkok Metropolitan Administration in their decision making process to select and handle waste management projects. The BMA provided relevant information and data for the construction of a mathematical formulation in line with their decision making process in order to solve the existing problems with a successful evolutionary algorithm.

4) This research demonstrated the importance of flexible contingency plan for handle and support municipal solid waste management system in emergency situation that will be beneficially to BMA and local administration.

1.4 Thesis Structure

Chapter 2 presents a literature review of the research applications for the environmental sector, multi-criteria optimization, evolutionary algorithms and performance measures for multicriteria algorithms. Chapter 3 presents the transportation model, the Vogel approximation method (VAM), which details the application of the multicriteria municipal solid waste management project of the BMA. In Chapter 4, a results of the VAM with multicriteria municipal solid waste management problems in the BMA is illustratel. Chapter 5 contains the conclusions of this research study and recommendations for further research.

1.5 Research Area

1.5.1 Content Area

This research study is only concerned with the municipal waste management system of Bangkok Metropolitan Administration (BMA).

1.5.2 Geographical Area

This research study mainly covers an area of fifty districts in the BMA, but in some parts of the research will be expanded to other provincial areas such as Nakhon Pathom and Chachoengsao (landfill disposal locations).

1) Research Population

The population in this research means BMA's officer and stake holder for gathering information and primary data by in-depth interview including the Deputy Director of BMA's department of Environment, the Director of Solid Waste Division, the Analist of Policy and Planning Division, the Engineering of Solid waste Division, Director of Onnut transfer station, Director of Nongkham Transfer station, Director of Saimai transfer station and the Director of Group 79 Co.,Ltd (landfill disposal sites at Nakornpathom).

In addition, population in this research means BMA's official node as a source site (fifty districts), transfer points (three transfer stations), incinerator and composting plants and two landfill sites. By designating each site as a node of the operation model based on their activities and using these node to calculate by VAM method.

2) Research Duration

This research project used 3 years period for conducting the research from 2015-2018.

1.6 Keywords and Definitions

1.6.1 Keywords

Municipal solid waste management, Bangkok Metropolitan Administration (BMA), Transportation Model (TM), Vogel Approximation Method (VAM) and Future study.

1.6.2 Definitions and Abbreviations

Transportation Problems (TP) is a special type of linear programming problem where the objective is to minimize the cost of distributing a product from a number of sources or origins to a number of destinations, Transportation Model (TM) a means of selecting the best way to distribute a product from a number of factories or warehouses to a number of destinations so as to minimize transportation costs while meeting customers' requirements., Vogel's Approximation Method (VAM) The Vogel Approximation Method is an improved version of the Minimum Cell Cost Method and the Northwest Corner Method that in general produces better initial basic feasible solution, which are understood as basic feasible solutions that report a smaller value in the objective (minimization) function of a balanced Transportation Problem, Bangkok Metropolitan Administration (BMA) is organized in accordance with the Bangkok Metropolitan Administration Act 1985, to be responsible for the management of the city of Bangkok. It is the sole organization at the local authority level responsible for the well-being of Bangkok residents with some financial support from the central government. The BMA comprises of two main bodies: the Governor and the Bangkok Metropolitan Council, Environmental Management System (EMS) refers to the management of an organization's environmental programs in a comprehensive, systematic, planned and documented manner. It includes the organizational structure, planning and resources for developing, implementing and maintaining policy for environmental protection, Solid Waste Management (SWM) is a term that is used to refer to the process of collecting and treating solid wastes. It also offers solutions for recycling items that do not belong to garbage or trash, Municipal Solid Waste Management (MSWM) includes the collection, transfer, resource recovery, recycling, and treatment of waste. The main target is to protect the population health, promote environmental quality, develop sustainability and provide support to economic productivity.

CHAPTER 2

LITERATURE REVIEW

2.1 Municipal Waste Management of Bangkok Metropolitan Administration

Bangkok Metropolitan Administration (BMA)'s municipal solid waste management system is founded empowering separate management functions at district and central levels; the first level is responsible for handling all operation systems, and the second for management policy and administrative methods. Fifty districts produce large amounts of waste which have to be transported to the areas. There are two types of waste, residential and commercial which are not similar in composition. The residential waste is mostly biodegradable waste but the most waste in commercial in origin and consists of paper and plastic, The collection crews on the collecting vehicles will separate recyclable matter while on route and when this is completed recyclable materials will be sold to recycling plants nearby. The waste collected this way is taken to a transfer station at 1) Saimai transfer station, 2) Onnut transfer station, or 3) Nongkham transfer station. Onnut transfer station only has recycle factory and composting plant and infectious waste incinerator, the others was not but at Nongkham transfer station has a waste incinerator. The composting plant makes fertilizer by composting from biodegradable materials such as food waste and garbage etc. Incinerator operate by Krungthepthanakom, a privatize company handle infectious waste from hospitals and clinics.

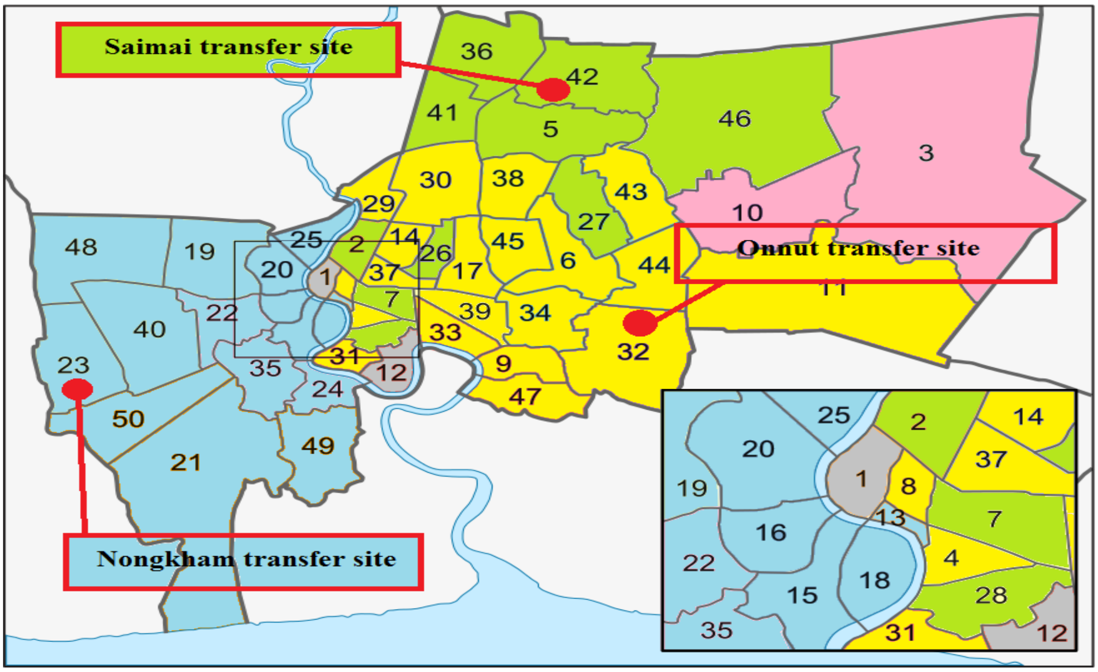

Figure 2.1 Fifty District Areas of Bangkok and Three Transfer Sites

Figure 2.1 shows the areas covered by the of Saimai, Onnut and Nongkham transfer sites. The Saimai transfer site covers green color district areas numbers 2, 5, 7, 26, 27, 28, 36, 41, 42 and 46. Onnut transfer site covers yellow color district areas number 4, 6, 8, 9, 11, 14, 17, 29, 30, 31, 32, 33, 34, 37, 38, 43, 44, 45 and 47. Nongkham transfer site cover blue color district areas number 13, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 35, 40, 48 and 50. The pink areas 3 and 10 are overlapping areas between the Saimai and the Onnut transfer sites and the gray areas 1 and 12 mean overlap with all three transfer sites.

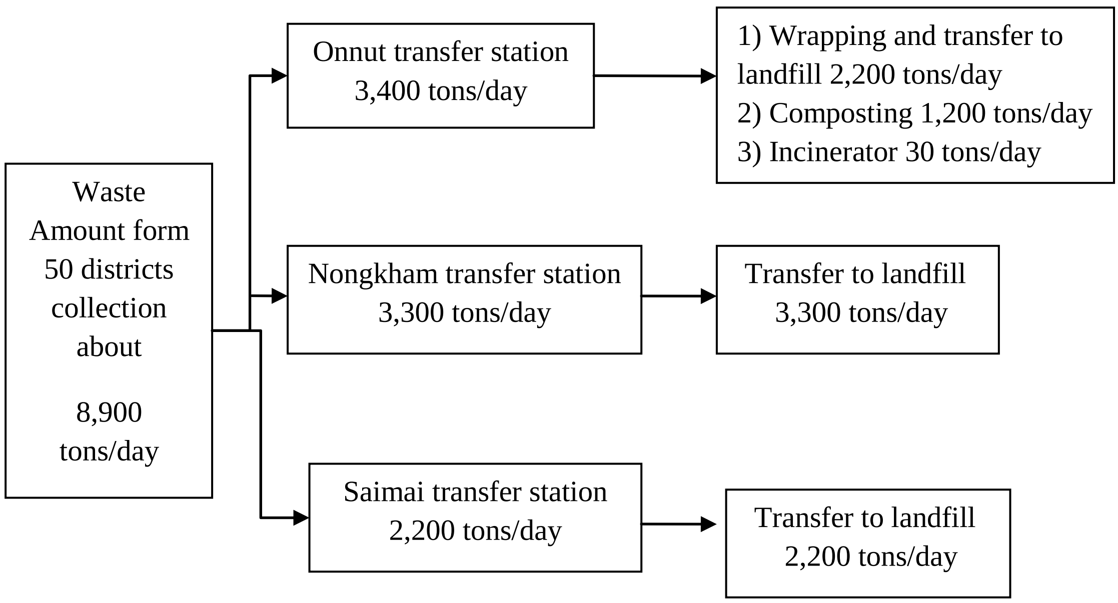

Figure 2.2 BMA Waste Management Line
Source: Bangkok Metropolitan Administration (2010).

Figure 2.2 shows the maximum loads each day for the BMA's three transfer sites, Onnut receives municipal solid waste from twenty-three districts daily. When the district crews finish the collections in their area, the vehicles deliver waste to the transfer sites for weighing it and dumping it into wrapping factory waste yard for feeding it to the waste wrapping process before it is transferred to the disposal site at Chacheongsao province in the eastern of Bangkok. Onnut station receives about 3,400 tons of waste per day and that amount equals nearly 40 percent of all the waste in the system. At the Onnut site there is a waste wrapping factory which has a capacity of 2,200 tons a day, one composting plant that receives biodegradable waste from many sources through a composting system which amount to 1,200 tons a day for fermentation process with a carrying capacity and Incinerator for infectious waste at capacity of 30 tons per day. Nongkham transfer station receives municipal solid waste from seventeen districts daily. When the district crews finish the collections in their areas, vehicles deliver waste through this transfer station for weighing and open dumping for scavenging. After scavengers have rummaged through the waste, it is transfer to Nakhonpathom disposal site. The Nongkham site receives about 3,300 tons of waste a day which is nearly 40 percent of the whole waste management system.

Saimai transfer station receives municipal solid waste from fourteen districts daily. Vehicles will transfer the waste to the Saimai site for weighing and dumping to vehicle heading to disposal site at Chachengsao same Onnut transfer station. About 2,200 tons of daily waste deliver to Nongkham site, which is nearly 20 percent of the total whole amount of solid waste in the system each day.

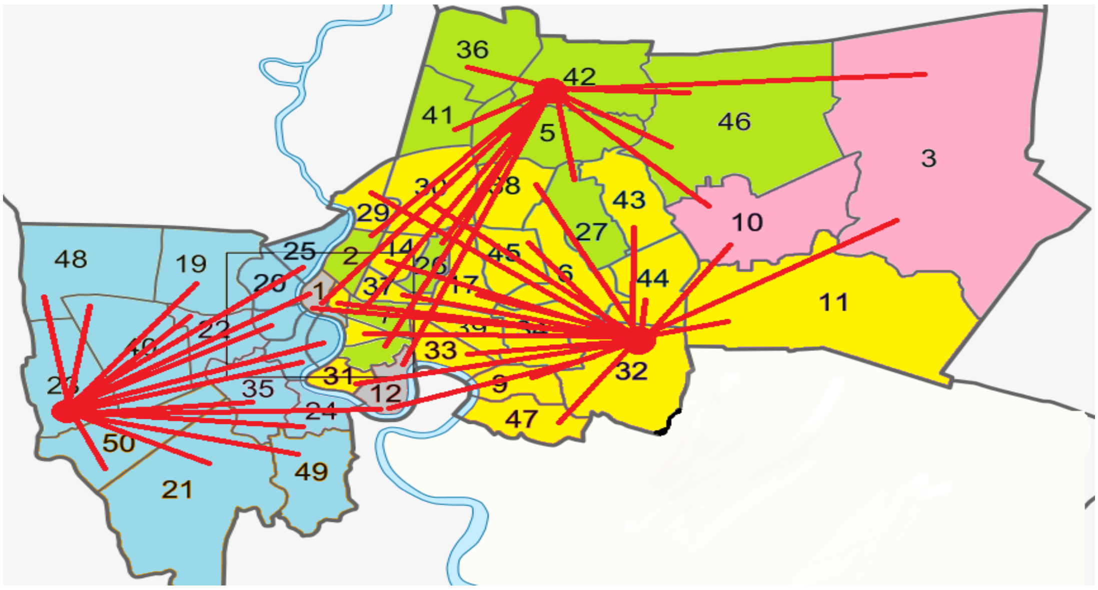

Figure 2.3 Areas of Responsibility of the Three Transfer Stations

From the Figure 2.3 above, it can be seen that the three transfer stations are responsible for three areas surrounding on their bases. However, many districts in the inner city, such as district number 2,7,26 and 28 that should transfer to Onnut transfer station, but they diliver to Saimai transfer station instead. In the overlapping districts number 1, 3, 10 and 12, there is not any clear information about the operation systems or schedules in these areas. This will be dealt with and corrected in the filed study stage.

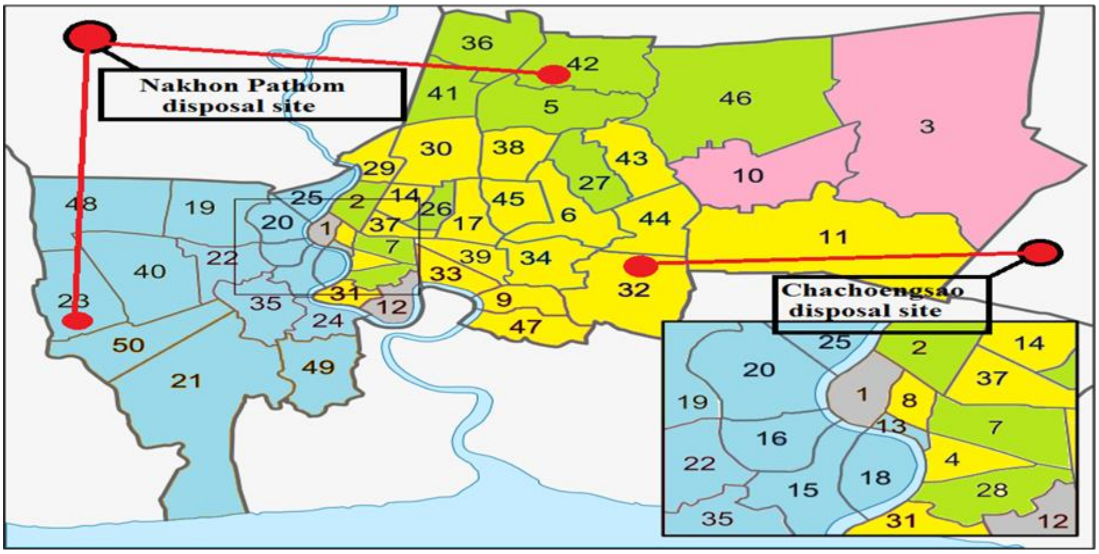

Figure 2.4 Disposal Sites

Waste is delivered to transfer station for final disposal in landfill sites. Bangkok municipal waste management system use two disposal sites located in Chachoengsao province and Nakhon Pathom province.

The current typical municipal solid waste collection has been eliminated by sanitary landfills, the main method and the last destination of all kinds of waste. This accounts for more than eighty percent of all solid waste which is totally terminated. On the other hand, solid residue treatment technology for fertilizers is carried out by composting biodegradable materials that account for nearly half the waste collected every day (Department of Environment, 2013). After waste separation, Bio-waste is transported to three waste transfer stations at Onnut, Nong Khame and Sai Mai it will be delivered to a composting plant where garbage is treated. Incinerators are used to destroy hazardous waste and other waste materials are destroyed at Onnut transfer station and at Nongkham transfer station in the future.

Today, the amount of municipal waste continues to increase rapidly as a result of economic development and also as a result of the population growth. There are obvious problems at present with the site capacity of the landfills. In the near future, sites will need to be replacing, so will become a major environmental problem. It will be necessary to resolve handling issues and to reduce waste by separation at its point of origin.

Bangkok is planned to be the center of the greater ASEAN in the Political - Security community, the municipality of democracy in the region, the center of the network and a metropolitan hub of ASEAN. The governor of Bangkok has announced explicitly that Bangkok will be the transportation hub of the region and the center of the region's logistics. These are the main objectives for the development of Bangkok to support the AEC by 2015.

In this context, the BMA should prepare for its AEC citizens and aliens in Thailand especially with regard to its handling of waste. The volume of waste may increase enormously after the integration of other ASEAN member countries. In addition, waste disposal rate of Bangkok citizens is increasing each year. One of the solutions to these problems of course is the segregation of waste at origin and the adoption of the Reduce, Reuse, Recycle (3Rs) philosophy.

But to be able to solve all the problems, it is necessary to know all the stakeholders' feedback and their complex relations between the BMA officers, the Business sector, Public sector, NGOs, Scholars and Bangkok citizens as well. This research aims investigate the issues that need to be faced in order to find the suitable solutions through the formulation of action plans. Nevertheless, aside of the investigation of the stakeholders, this research plans to define the operational problems for all waste disposal processes.

The research components will demonstrate the current situation of BMA's municipal solid waste management. Of course, this does not include the waste discharge rate growth because of population increases when the AEC opens. The research will project the amount of waste creation in the nearly future and the present threats of waste quantity increases based on population number in Thailand and the waste creation rate by using a model creation technique.

On the basis of the current and future situations, it will be necessary to develop a clear vision of the future problems and threats. This research will suggest solutions to the problems from academic view of the BMA and for concerns about the present situation and future prospects with regard to management schemes based on a sustainable development concept.

2.2 Challenges of Waste Management in Bangkok

Bangkok City waste management is a challenging and demanding voice of the people throughout the ages that will change the governor. Relive Bangkok Office starts from Bangkok Development Plan No. 1 (1977-1981) until the current 2013 hardly any strategic plan for solid waste management to real success. A survey of public opinion on the success of the Bangkok governor according to a leader article on the administration "NIDA poll" between 9 to 24 October 2012, stated that the work of the governor of Bangkok has never achieved more success in the field of waste management and contamination than 21.50 percent, while the general public idea considers that success is only 15.60 percent.

Economic activity and urban growth increased rapidly in the absence of environmental management practices, policies, adequate and efficient urban expansion of the city has led to environmental degradation in Bangkok. One of the major problems that continue to challenge the city administration throughout the decades is the "overflowing city garbage problem", which is deteriorating at an alarming rate.

"Waste" is a huge problem. Bangkok has set targets for waste management in new guidelines. Reducing the amount of waste, garbage and recycling aims to encourage all sectors to participate in reducing waste and to put the 3R principles into practice. The Bangkok Development Plan No. 4 (1992-1996) proposed a strategic plan into 3 main parts: 1) control the amount of solid waste by trying to develop public consciousness. 2) Optimize the waste separation on hazardous waste and residue-fat sources by increasing the capacity for solid waste, hazardous waste, food waste, and promote lipid sorting, household waste, and 3) support the production of technical processes by obtaining the technological support and expertise from businesses in the private sector. This was a reasonably good plan, but the practical and pragmatic solutions that followed it were not impressive.

Table 2.1 Waste Generation between 2005-2011

AREA	**Amount of Easte Collection per day (tons)**						
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
BANGKOK	8,291	8,403	8,532	8,780	8,834	8,766	9,126

Source: Department of Environment (2012).

The statistics for the amount of waste occurs each year is shown in the above table. Garbage in Bangkok continues to increase by about 2 percent per year and it may be concluded from this that the waste disposal system used in the past has not been as successful as it should have been. Although the Environment Agency has carried out many projects in Bangkok, the main strategy has been to create the concept of waste management in the community, for example, the promotion of waste separation in the school projects and processing food waste into organic fertilizers. There have also been waste separation pilot projects on recycling waste at recycling stations. Also the use of bio- gas digester tanks has been promoted. Reduction and waste separation by the participation of 12 pilot communities, which can reduce the amount of solid waste is estimated at about 10 percent per year in the project area. However, evaluation methods used by the Environment Agency predicted the amount of garbage compared to predictions of JBIC. Since 2011, BMA cannot be used as a measure of the success of the project because the incidence of future solid waste is calculated the estimated gross domestic product in the future.

Table 2.2 Waste Reduction in Bangkok between 2005-2009

Year	Expected Waste Quantity (tons/day)	Collection Amount (tons/day)	Waste Reduction Compare with Expected Waste Quantity	
			Tons/day	Percentage
2005	9,388	8,496	892	10
2006	9,546	8,377	1,169	12
2007	9,706	8,718	988	10
2008	9,847	8,780	1,067	11
2009	10,000	8,787	1,213	12

Source: Bangkok Metropolitan Administration (2010).

The failure to successfully manage waste is now clearly. The BMA has not been able to persuade Bangkok citizens to reduce waste before disposal, so this remains a problem to be solved. Memorable and successful projects in the past, for example, "The Magic Eye (Ta-Vi-Set)" that made people start to realize the importance of not throwing litter on the ground floor and in rivers was not conducted directly by to the government or Bangkok, but it was a project of the private sector. Bangkok, which should have followed the example of such campaigns and should adopt a similar solution in the current budget.

Another important type of waste is hazardous waste. This type of waste in Bangkok has still not been able to meet the target of the Bangkok Development Plan No. 5 (AD 1997-2002), but the execution of the plan continues although not seriously enough, for example, the public should separate hazardous waste in households across 50 districts but the public will have ejected hazardous waste into grey-red tanks. Collection vehicles will keep it on the 1st and 15th day of each month or even more frequency in the case of huge amounts of waste. Bangkok has prepared a project to promote effective management of hazardous waste from the community. Tanks for hazardous waste have been designed by two separate buckets of fluorescent lamps and the other light bulbs, spray tanks, pesticides, they aimed to keep the hazardous waste at 24-30 tons per day, but it turns out that Bangkok can only store hazardous waste at an average of only 600 kg per day.

From the past to the present, the Environment Agency BMA has lost spent large amount of its budget on sending staff to work abroad to learn how to organize campaigns to educate the people and their communities. But the problem sorting the waste adequately has been abandoned, so it has not been fully integrated into a sustainable management system. There are various reasons for this failure. But it has to be acknowledged that such problems are caused by the inefficient management of BMA. For example, BMA currently has nowhere to educate people and train people in the correct methods of separating garbage before disposal. Therefore the campaign about public waste was not successful, because when people dispose of waste, they do not separate it into tanks, as most people feel that will not be separated at the garbage district office but only tipped there or become a function of Zaleng – a type of recycler, to be isolated.

The key question is “Why has the screening of waste management been abandoned and sustainable waste management has not taken place in Bangkok?”, Bangkok itself has had many projects that promote waste reduction and separation. These campaigns have encouraged people to separate waste over the past several decades.

Table 2.3 The BMA Annual Budget 2008-2013

Year	General Management (1,000 Baht)	Percent	Development and Support (1,000 Baht)	Percent	Cleaning (1,000 Baht)	Percent	Total (1,000 Baht)
2013	88,151	1.69	140,806	2.71	4,967,665	95.59	5,196,623
2012	99,808	2.91	82,524	2.41	3,240,806	94.67	3,423,139
2011	122,595	5.43	34,973	1.54	2,099,550	93.01	2,257,119
2010	119,673	5.10	15,247	0.65	2,207,874	94.24	2,342,795
2009	55,800	2.09	24,604	0.92	2,580,384	96.97	2,660,789
2008	49,421	2.09	61,303	2.60	2,243,429	95.29	2,354,154

Source: Bureau of the Budget (2013).

The Governor of Bangkok as announced that reducing waste and recycling so that resources are used is well worth it. To solve Bangkok's sustainable waste management and reduce the degradation of the environment, the Environment Agency for Bangkok, which is the agency with responsible for the waste management has a budget for almost all aspects of cleanliness and tidiness, which has been allocated to project procurements, by hiring private contractors over 10 years ago the total of which amounted to billions of baht, including garbage collection contracts. Waste collection fees in Bangkok can only cover a very small number of people compared to the actual cost paid for waste collection. One reason is because Bangkok is still using the old rate and no new rate has yet been introduced, because the regulations on fees in Bangkok for the collection and transport of sewage or solid waste do not take public health issues into account. The database is a comprehensive collection target which is a major limitation since the authority can-not be fully charged.

Table 2.4 Bangkok Waste Collection Fees

Number	**Provisions**	**Waste Collection fees by month (Baht)**
1	Not in excess of 20 litres a day	20
2	In excess of 20 litres but not in excess 500 litres a day	40
3	In excess 500 litres but not in excess 1 cubic metres a day	2,000
4	In excess of 1 cubic metre a day	2,000

Source: Bangkok Metropolitan Administration (2010).

Part of the budget is spent on hiring private vehicles, which may be due to a lack of transparency in the procurement process. There is little public awareness of the benefits of waste separation. Since all the technology used in waste disposal should eliminate waste efficiently when used appropriately, thus technologies have been developed, such as composting and making biogas from food waste, and recycling used paper and clay, etc. So, although Bangkok has projects for waste reduction and separation, there is only a very limited budget. Consequently, it is very difficult to achieve any significant results.

Although it is clear and widely accepted worldwide that the reduction and separation of waste is the most sustainable solution for waste management, since 2013 Bangkok has returned to solid waste incineration technology for the treatment of solid waste and sewage, in spite of considerable public opposition to the use of incinerators. Both locally and abroad incinerators pose risk of carcinogenic dioxins which cause severe environmental and public health hazards. Moreover, the removal of toxins such as dioxin, requires a complex and expensive system. Therefore, it is extremely risky to use incinerators and there are no strict domestic laws to cover their use. The authorities who are responsible such as BMA, however, are still not listening to the public and a contract has been signed for hiring of private waste disposal systems using incinerators for the destruction of 300 tons per day of solid waste disposal per day.

Lack of transparency in Bangkok, as mentioned above may be one of the causes of failure in the service of sustainable waste management. But the most important thing is that to make Bangkok, a true paradise, the dream is still dependent on the contributions and responsibilities of each person living in the area.

2.3 Transportation Model

2.3.1 Introduction

The Transportation Model is a model for the transportation of resources between the various sources. For example, shipping from a warehouse to a customer in a different location or transporting goods from a production source go to different warehouses by paying the lowest shipping cost or take the minimum transit time or others objective at each receiving warehouse the number of different products.

2.3.2 Brief History of Transportation Model

Transportation routes need to be carefully considered since consideration it is well-known that the costs of transferring products from a source to its destination is one the keys to optimizing profits. Shorter transportation distance results in higher operational efficiency. Suitable models require special designs and techniques to solve transportation problems, which include availability of supplies at sources and delivery to specific at destination points. In logistics, transportation models can be used to determine how to allocate the availability of supplies from the various factories to plants, in such a way that the total shipping costs are minimized (Horowitz, 1972).

Generally, a transportation model requires linear calculations, which are designed to find solutions to the specific purposes of different transportation problems. A few of these steps are included in the following titles (Hakim, 2012) (Das, Babu, Khan, Helal, & Uddin, 2014), which commonly identify the transportation parameters on a 'transportation matrix' and then calculate the parameters according to the method of each model.

2.3.3 Review of Transportation Models

This section discusses the commonly-used transportation models in logistics process; Northwest Corner Method (NWCM), the Least Cost Method (LCM) and Vogel's approximation method (VAM). A comparison of these alternative model os discussed below.

2.3.3.1 Northwest Corner Method (NWCM)

The Northwest Corner Method is used to meet a plant's demand onsite for the resources available. According to a transportation table, which shows the feasible shipments for any transportation problems, with calculations beginning at the Northwest corner of the table to allocate the maximum possible demand in order to meet with plant capacity or availability. If the availability of the source meets the demands of plants formally, then it is possible to proceed to the next stage. After going to the nearest source, and then repeating the allocation process by starting with the first (lowest index) destinations where demand has not been fulfilled, then the process can be repeated until all the sources are allocated (Gupta & Hira, 2008).

The following method starts at the northwest-corner cell in transportation matrix.

1) Allocate as much as possible to the selected cell, adjust the associated amounts of supply, according to a availability from sources and demand of plants by subtracting the allocated amounts.

2) Cross out the row or column for zero supply or demand in order to indicate that no further assignments can be made. When both rows and columns are equal to zero simultaneously, cross out one only and leave a zero supply (demand in the uncrossed-out row).

3) If exactly one row or column has not been crossed out from another side row or column, stop the calculation and move to the next right or cell below until finishing the calculation. The next step is to return to step 1 to complete the table. If a column has just been crossed out, or below if a row has been crossed out.

A sample of the Northwest Corner Method (NWCM) is shown in Table 2.5.

Table 2.5 Illustrated Computation of Northwest Corner Method

Plant A			**Plant B**		**Plant C**		**Availability**
Source 1		1st	3	2nd	5	8	300
	150		150				
Source 2			7	3rd	4	7	100
Source 3		6	4th	5	5th	9	400
		200		200			
Demand	150		450		200		800

1st	150	X	3	=	450
2nd	150	X	5	=	750
3rd	100	X	4	=	400
4th	200	X	5	=	1,000
5th	200	X	9	=	1,800
					$4,400

The computing method starts with consideration of A1 with the total number of resources' in demand from Plant A, while Source 1 provides the availability of 300 in total. As a result, there are resources left in Source 1. Hence, the suggested method is to move the left of matters into Plant B. Therefore, B1 consists of an other 150 resources, although the total demand for Plant B has not yet been completed. Another nearest source are needed to fulfill its capacities, consider to Source 2's availability in total number of 100 resource units (see B2).

Consequently, consider another available nearest source, Source 3. To obtain, move the left of the calculation of Plant B to the cell bellow in Source 3 (see B3), to achieve total availability of Source 3 which is able to provide 400 resources. Accordingly, complete table for an allocation 800 resources by implementing the Northwest Corner Method to perform the calculation. Finally, calculate the cost and the number of resources allocated, and the total result is $4,400.

The Northwest Corner Method produces quick solutions to the calculations, but the results presented deal with the cost of transportation unsystematically, and do not provide an from optimal solution. Since the transportation model in the table has not been organized well neither with regard to cost or distance.

2.3.3.2 The Least Cost Method (LCM)

This method allocates the most possible to the every next least-cost cell. Ties may be broken arbitrarily. Rows and columns that have been completely allocated are not considered, and the process of allocation is continued. Therefore, the procedure is completed when all the requirements of the rows and columns are addressed according to the cost of each locations.

The Least Cost Method is an intuitive approach, with cell allocations made according to cell costs, beginning with the lowest cost to the higher cost of transportation by trying to eliminate resources with costly solution.

The following method shows the cell steps with the lowest considered cost in the transportation table.

1) Identify the cell with the lowest cost in the transportation table.

2) Allocate as many units as possible to that lowest cost's cell, and cross out the row or column (or both) that is exhausted.

3) Find the cells with the next lowest cost from among the feasible cells.

4) Repeat steps (2) and (3) until all units have been allocated.

A sample of the Least Cost Method (LCM) is shown in Table 2.6. The calculation begins at the lowest cost, which is cell A1. Comparing demand and availability show that Plant A has a lower demand than is available from Source 1. Therefore, the demand of Plant A will be crossed out when 150 resources in cell A1 are filled number of 150 resources. Then, allocate to the next higher transportation cost (see B2), Source 2 provides lower capacity of resources compare to demand, therefore, 100 units availability's units are crossed out (see B2).

Table 2.6 Illustrated Computation of Least Cost Method

		Plant A		**Plant B**			**Plant C**			**Availability**
Source 1			1st	3		5	4th		8	300
		150				150				
Source 2				7		2nd	4		7	100
				100						
Source 3				6		3rd	5	5th	9	400
				350			50			
Demand		150		450			200			800
1st	150	X	3	=	450					
2nd	100	X	4	=	400					
3rd	350	X	5	=	1,750					
4th	150	X	8	=	1,200					
5th	50	X	9	=	450					
					$4,250					

Thus, there are 350 resource's demands left to Plant 2 (350 units) to be kept for further consideration. To continue, search for the next higher cost. In this case, there are two alternative cells (B1 and B3), taking intoconsideration that due to the higher number of sources available, Source 3 gives a higher number (400) compared to Source 1 for which 150 units are available. Therefore, Source 3 should be selected to allocate the lower demands 350 units, hence Plant B's demand has been completed. Next, consider the higher transportation costs which are shown to be less in Plant C. The cost of $8 is selected since for the cost of $7 there are no resources available to allocate. Hence, Plant C's demand for 150 units (see C1) is satisfied and 50 units in cell C3, respectively. Finally, calculated costs and the number of resources are allocated with a total transportation cost of is $4,250.

The method of the Least Cost is focuses on the lowest costs, which reduced the costs of transportation (Loomba & Tuban, 1927). Nonetheless, the computing pattern does not take distance into account as priority.

2.3.3.3 Vogel's Approximation Method (VAM)

Vogel's Approximation Method (VAM) is the most effective algorithm for solving transportation problems, as it gives optimal solutions which differs from those of other methods. The VAM approach is calculated from penalty cost, as a calculated cost of opportunities. In this case, transportation charges with result to the spending on higher penalty cost routes, while cheaper cost routes were skipped-over.

VAM considers cost allocations which usually produces an optimal or near-optimal starting solution. This calculating model of VAM uses more calculation processes compared to other methods (Shore, 1970), but the results provide more specific initial solutions to obtain an optimal solution.

The calculation procedures of VAM consist of the following steps:

1) Each row or column, determines a penalty measure by subtracting the smallest unit cost element in the row or column from the next smallest unit cost element in the same row or column.

2) Then the row or column with the largest penalty can be identified. Any ties are broken arbitrarily. Then as much as possible should be allocated to the variable with the least unit cost in the selected row or column. Next, adjust the supply and demand by crossing out the highest penalty number on a row or column. If a row and column give a similar number of penalty costs, then select the lower cost of transportation in order to cross out the remaining supplies and demands.

3) Step 1 and step 2 should be repeated in order to make supply and demand equal to zero.

A sample of Vogel's Approximation Method (VAM) is shown in Figure 3, where the most suitable resource allocation point is A1, since its penalty cost, which is calculated by the difference between the two lowest costs in each row and column ($6-$3 = $3 in column A), results in the highest penalty cost and the lowest cost of transportation. As, 150 resources were allocated in A1, Plant A's demand is thus satisfied. Nonetheless, Source 1 has the lowest amount 150 resources as only 300 supply units are available. Next, B3 is allocated 400 resources units since its row penalty provides highest number ($9-$5 = $4), therefore the highest possible amount of resources meets the availability. Thus, 400 units were allocated to complete Source 3 availability. B2 collects 50 resources since its penalty cost is the highest number, compared to the less of B1, B2, C1 and C2. Then, the remaining 50 demands are crossed out for Plant B. 50 resources units should be allocated to Source 2-Plant C, and 150 units to Source 1-Plant C to make up the total availability respectively. In the end, the total transportation costs are $4,200.

Table 2.7 Illustrated Computation of Vogel's Approximation Method

	Plant A			Plant B		Plant C			Availability
Source 1			1st	3	5	5th		8	300
		150			150				
Source 2				7	3rd	4	4th	7	100
				50		50			
Source 3				6	2nd	5		9	400
				400					
Demand		150		450		200			800
1st	150	X	3	=	450				
2nd	400	X	5	=	2,000				
3rd	50	X	4	=	200				
4th	50	X	7	=	350				
5th	150	X	8	=	1,200				
					$4,200				

The computing pattern of VAM is complicated, due to the requirement the regret to be the first priority followed by the cost of transportation, in order to obtain the final result (Mahto, 2014).

2.3.4 Transportation Model Analysis

Table 2.8 shows, the total costs in dollars as a result of the computations, which represents the achievement of the selected transportation model calculating methods in overall performance. The Least Cost Method and Vogel's Approximation Method are able to achieve optimal costs associated with the optional routes for transportations. However, the Northwest Corner Method is not able to deal with the cost of transport from the sources to the plants.

Table 2.8 Comparison of the Transportation Models

No.	Computing Criteria	NWCM	LCM	VAM
1	Results from Samples	$ 4,400	$ 4,250	$ 4,200
2	Transportation Costs	X	□	□
3	Penalties	X	X	□

In conclusion, VAM yields the best basic solution since it provides the initial solution which is very near to the optimal solution. However, Vogel's Approximation Methods does not take into account the calculated penalties for contemplation and decision-making.

The Use of the Transportation Model for MSW waste collection services

The Bangkok Metropolitan Administration (BMA) currently has three waste transfer stations at Saimai, Onnut and Nongkhaem. BMA currently provides the MSW collection service to its 50 districts by using at least 129 waste-collection trucks every day. It is estimated that the average waste load is roughly 780 tons/day. The most critical districts are Jatujak, Dindaeng and Bangsue which often have accumulated MSW at the temporary storage sites within the districts. One of the reasons for this is the heavy traffic in Bangkok which causes individual waste-collection trucks to be stuck in certain area for long periods of time. On average, each truck makes a roundtrip of between 40 to 72 km. Normally the trucks can make 1 to 2 trips in each day. In addition, the waste collection trucks themselves also cause traffic problems, especially on the secondary roads or small alleys. Thus the use of a suitable transportation model to select the optimal waste-collection route would help save a significant amount of time and energy as reducing air pollution (Kingmongkut's University of Technology North Bangkok, 2015).

CHAPTER 3

MODEL DEVELOPMENT

3.1 Conceptual Framework and Research Type

The first stage of the research was to figure out issues that significantly affect BMA's municipal solid waste management, in terms of management cost and efficiency. Qualitative techniques was used to study the internal management system. However, primary data collection and analysis were also used in this research. Therefore, this research is a rather mixed method research using both quantitative and qualitative approaches. One of the advantageous characteristics of conducting mixed methods research is the possibility of triangulation, i.e., the use of several means (methods, data sources and researchers) to examine the same phenomena as summarized in Figure 3.1.

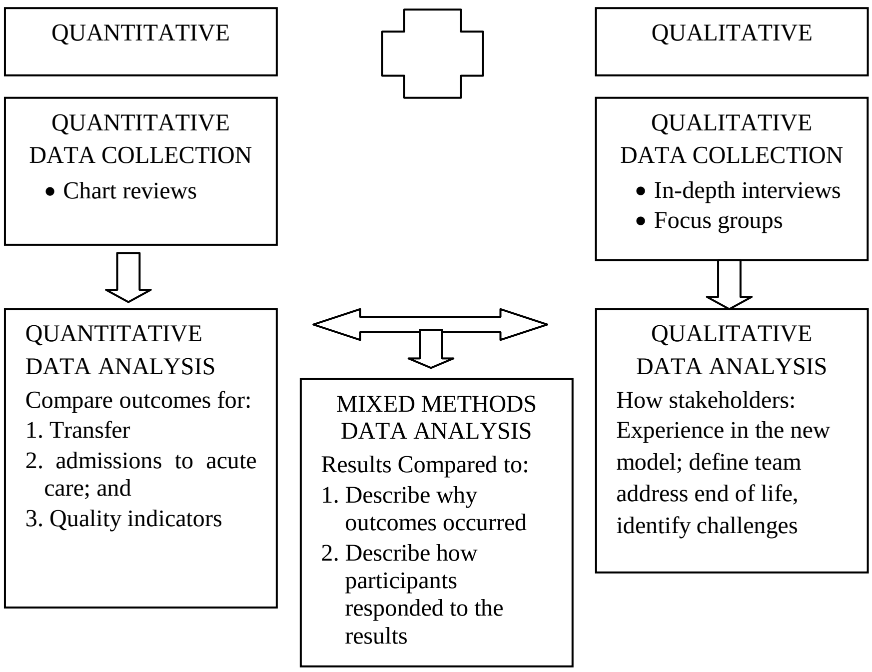

Figure 3.1 Concurrent Triangulation Design

Source: Adapted from Creswell and Clark (2011).

In qualitative method, researcher collection data from the BMA's officer and stake holder for gathering information and primary data by in-depth interview including the Deputy Director of BMA's department of Environment, the Director of Solid Waste Division, the Analist of Policy and Planning Division, the Engineering of Solid waste Division, Director of Onnut transfer station, Director of Nongkham Transfer station, Director of Saimai transfer station and the Director of Group 79 Co., Ltd (landfill disposal sites at Nakornpathom).

The quantitative method in this research means BMA's official node as a source site (fifty districts), transfer points (three transfer stations), incinerator and composting plants and two landfill sites. By designating each site as a node of the operation model based on their activities and using these node to calculate by VAM method model.

3.1.1 Research Conceptual Framework

The research process cycle was selected and started with gathering information from many sources including both primary and secondary sources. The primary data collection by in-depth interview including the Deputy Director of BMA's department of Environment, the Director of Solid Waste Division, the Analist of Policy and Planning Division, the Engineering of Solid waste Division, Director of Onnut transfer station, Director of Nongkham Transfer station, Director of Saimai transfer station and the Director of Group 79 Co., Ltd (landfill disposal sites at Nakornpathom). The secondary data collection by cooperating from the BMA's Policy and Planning Division. After analyzing the information, the problems were identifies. Then the researcher selected the most important problems of the BMA and then designed the research methods and started to conduct the research until the results were obtained. In this research, the most important problems of the BMA included overlapping waste transport route. Then, the transportation model was selected to use as a simulation tool to compare results of different scenarios. After communicating the findings, the researcher applied the results and made recommend to the BMA.

The research process cycle

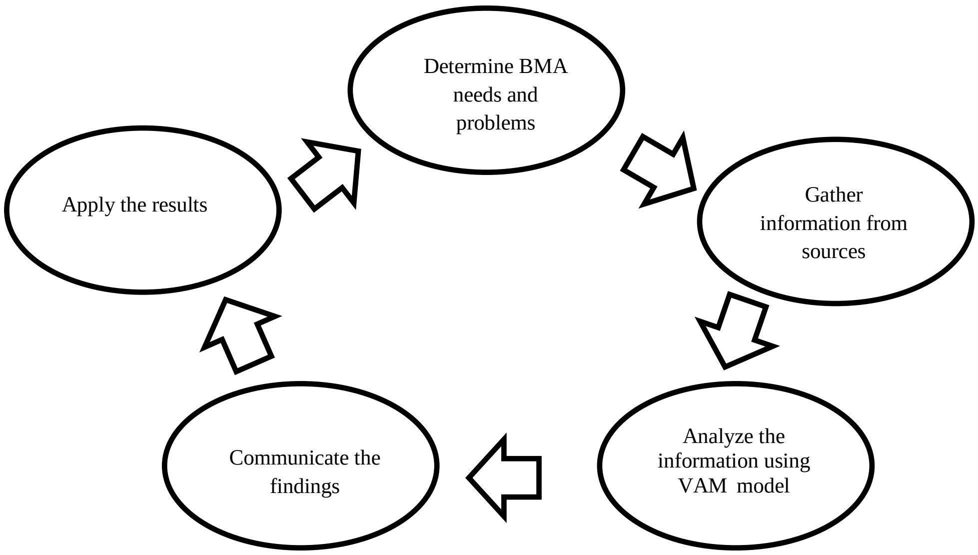

Figure 3.2 Research Process Cycle
Source: Adapted from Bailey (1987).

3.2 Model Development

The content of the research mentioned in the previous section is described using a graph-based model as shown in Figure 3.1, from which it was proposed to clearly explain the context of the BMA's current management situations.

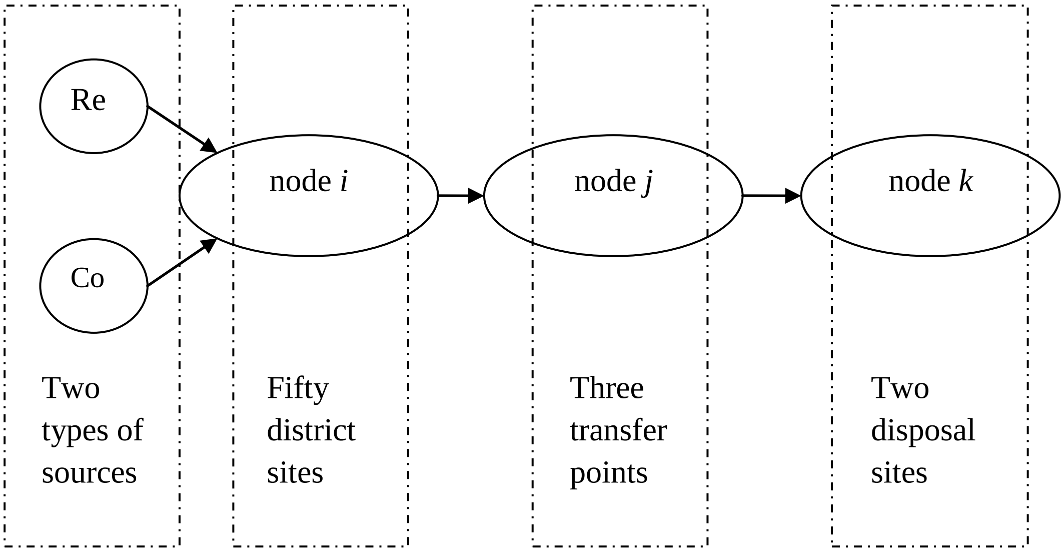

Figure 3.3 BMA's Municipal Solid Waste Management System

In the model, BMA as well as a municipality, is represented as a node in the graph. In current practice, each district administration collects and transfers all wastes to three transfer station sites where all materials are disposed of. There are two types of waste, residential (Re) and commercial (Co) which is not similar in composition. The residential waste is mostly biodegradable waste but the most waste in commercial in origin and consists of paper and plastic, the collection crews on the collecting vehicles will separate recyclable matter while on route and when this is completed recyclable materials will be sold to recycling plants nearby. The waste collected this way is taken to a transfer station at 1) Saimai transfer station, 2) Onnut transfer station, or 3) Nongkham transfer station. Onnut transfer station only has recycle factory and composting plant and infectious waste incinerator, the others was not but at Nongkham transfer station has a waste incinerator. The composting plant makes fertilizer by composting from biodegradable materials such as food waste and garbage etc. Waste is delivered to transfer station for final disposal in landfill sites. Bangkok municipal waste management system use two disposal sites located in Chachoengsao province and Nakhon Pathom province.

The question is in the current issues is how to allocate the right amount of waste to transfer station by most efficiency and minimize cost., according to a set of objective functions and constraints, as discussed in the next section.

3.3 Model Formulation

As mentioned earlier, the transportation of municipal solid waste of BMA is rather a complex issue. Vogel's Approximation Method (VAM) is, therefore, used a tool to optimize the transportation route and cost of the system. The research problem is to determine an optimal transportation scheme that can minimize the total transportation costs between the nodes in the network model, which subjected to supply and demand constraints. In this research, supply and demand constrain was for the amounts of waste from each BMA's district (fifty districts), while the supply constrain was the capacity of each transfer station

In the model, there are several original points to several destinations. Suppose there are m points of original $A_1, . . ., A_i , . . ., A_m$ and n destinations $B_1, . . ., B_j , . . ., B_n$. The point $A_i (i = 1, . . ., m)$ can supply a_i units, and the destination B_j ($j = 1, . . ., n$) requires b_j units (see Equation 1).

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_i$$

Equation 1.

While, the costs of transportation a unit from A_i to B_j , is computed as c_{ij}. In addition, the model will optimize the transport pattern at which shipping costs are at a minimum. Moreover, the requirements of the destinations B_j , j = 1, . . ., n, must be satisfied by the supply of available units at the points of origin A_j , i = 1, . . .,m. As shown by Equation 2, if xij is the number of units that are shipped from Ai to Bj , then the problem in determining the values of the variables x_{ij}, i = 1, . . ., m and j = 1, . . ., n, should minimize the total transportation costs.

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$$

Equation 2.

While

$$\sum_{j=1}^{n} x_{ij} = a_i; i = 1, \ldots, m$$

$$\sum_{i=1}^{m} x_{ij} = b_i; j = 1, \ldots, n$$

$$x_{ij} > 0; i - 1, \ldots, m \ and \ j - 1, \ldots, n$$

Mathematically, the transportation problem can be represented as a linear programming model. Since the objective function of this problem is to minimize the total transportation costs as given by Equation 3.

$$Z = c_{11}x_{11} + c_{12}x_{12} + \cdots + c_{mn} + x_{mn}$$

Equation 3.

Equation 3 is a mathematical formulation of a transportation problem that can adopt the linear programming (LP) technique with equality constraints. The LP technique can be used for different product areas such as the palm oil industry (Man, & Baharum, 2011). However, the LP technique can be generally used as a genetic algorithm such as Sudha at el. article (Sudha & Thanushkodi, 2012). The solution to the transportation problem can be found with successfully by improving the service quality of the public transport systems (Hefetz, & Warner, 2011). Also it is found in article (Ismail, Mahad, & Ching, 2011). Furthermore, solving the transportation problems is used in electronic commerce where the area covered is global and there is a the degree of competition between article (Norozi, Ariffin, & Ismail, 2010), and it can be also be used in scientific fields, such as the demands for transport using simulated data for bio-chemicals and Oxygen demands transport (Eisakhani, Abdullah, Karim, & Malakahmad, 2012), and in many other fields. However, there are several different algorithms to solve transportation problems that are represented in the LP model. Among these are the known algebraic procedures of the simplex method, which may not be the best method to solve the problem. Therefore, more efficient and simpler procedures have been improved to solve transportation problems. Typically, the standard scenario for solving transportation problems by sending units of a product across a network of highways that connect a given set of cities. Each city is considered as a source (S) in that units will be shipped out from, while units are demanded there when the city is considered as a sink (D). In this scenario, each sink has a given demand, the source has a given supply, and the highway that connects source with sink as a pair has a given transportation cost/(shipment unit). Figure 1 visualizes the standard scenario for cities on the highway in the form of a network.

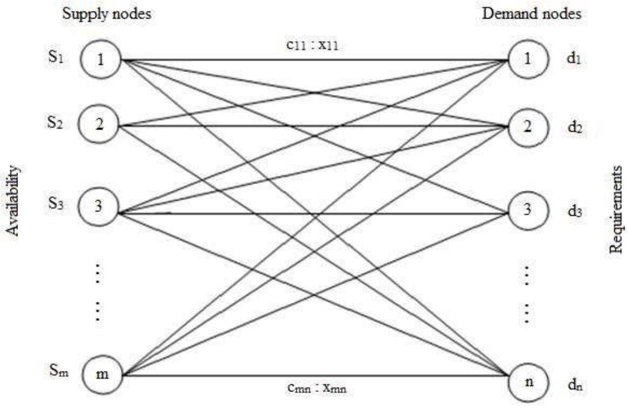

Figure 3.4 Network Flow Model for Transportation

As shown by Figure 3.1, the problem is to determine an optimal transportation scheme that can minimize the total the shipment costs between the nodes in the network model, subject to supply and demand constraints. Also, this structure used in many applications such as, the sources represent warehouses and the sinks represent retail outlets. In this research supply and demand was for the amounts of waste from each BMA's district (fifty districts) and the supply of transfer station waste with the capacity to receive the waste (three or four transfer stations) under constraints.

3.3.1 Model Formulation

Vogel's Approximation Method (VAM) is based on the code from HIOX Softwares Company, a developer of computational-based software. The code was modified for the width range of the data input.

Vogel's Approximation Method (VAM) code is shown in Appendix. Generally Vam can be summarized by the following three main steps:

i. The result of subtracting the smallest unit cost element in the row/column (cell) from the immediate next smallest unit cost element in the same row/column is determines a penalty measure for the target row/column.

ii. This step includes the following sub-steps:

a. Identify the row or the column that includes the largest penalty.

b. Break ties arbitrarily.

c. The lowest cost row/column (cell) in the row or column should be allocated with the highest difference wherever possible.

d. Adjust the supply and demand, and then cross out the satisfied row or column.

e. If a row and column are satisfied simultaneously, then only one of them is crossed out, as well as the remaining rows or columns which are assigned to supply as zero (demand).

iii. Finally, the result should be computed as follows:

a. If a row or a column is assigned as zero supply, or the demand remains uncrossed out, then stop the process.

b. If one row/column with positive supply (demand) remains uncrossed out, then determine the basic variables in the row/column by the lowest cost method, and then stop.

c. If all the uncrossed out rows and columns have (remaining) zero supply and demand then determine the zero basic variables by the lowest cost method and stop.

d. Otherwise, go to step (i).

After the code modification (member extension), the researcher ran the script and created a web page name *https://vamenvinida.com/* to use as tools to make the calculations. All results in this research were the results from this web page that was created by the researcher.

In this research, the BMA data is used to calculate the amount of waste from the BMA by 2015, which is calculated as a unit cost. The formulas are based on research conducted by the Waste Incineration Research Center (WIRC) Department of Mechanical and Aerospace Engineering, King Mongkut's University of Technology North Bangkok. Pages ข-13, as shown below.

The cost of transporting the waste to the transfer station = the average distance from the area to the loading station x travel fuel loss (1.5) x travel to and from (2) x Index of end Fuel consumption/liter/ton/ton (0.144) x average daily amount of waste

The distances available from the Google map were used to evaluate driving distance of waste transport trucks from all districts in the BMA to all transfer stations, namely Bangkhen, Onnut and Nongkhaem including the new station at Ratchavipha. Diesel fuel price is calculated at 30 Baht/liter. Fuel consumption is 0.144 liters/ton.

CHAPTER 4

RESULTS

Bangkok Metropolitan Administration (BMA) is accounting for daily municipal solid waste management through the Solid Waste Disposal Division (SWDD) controlling by Department of Environment (DE). SWDD has responsibility for controlling solid waste disposal effectively and sanitation according to technical principles, laws and related regulations, including implementing engineering works related to public cleansing and environment. SWDD control subdivisions those related directly to municipal solid waste management system including Saimai solid waste disposal center, Onnut solid waste disposal center and Nongkham solid waste disposal center. These three solid waste disposal centers were used as transfer station, they received municipal solid waste from fifty districts of Bangkok area daily and transfer to landfill. All three transfer stations are under the control of BMA whereas some related activities are operating by private sector, for example waste separation, out bound waste transportation and sanitary landfill operation.

4.1 Current Situations

According to daily waste data base gathered from three transfer stations of BMA at Saimai, Onnut and Nongkham site, recording from 1st March 2014 to 7th March 2014 which demonstrated the daily average amount of solid waste collection from fifty districts of the BMA is shown in the Figure 4.1

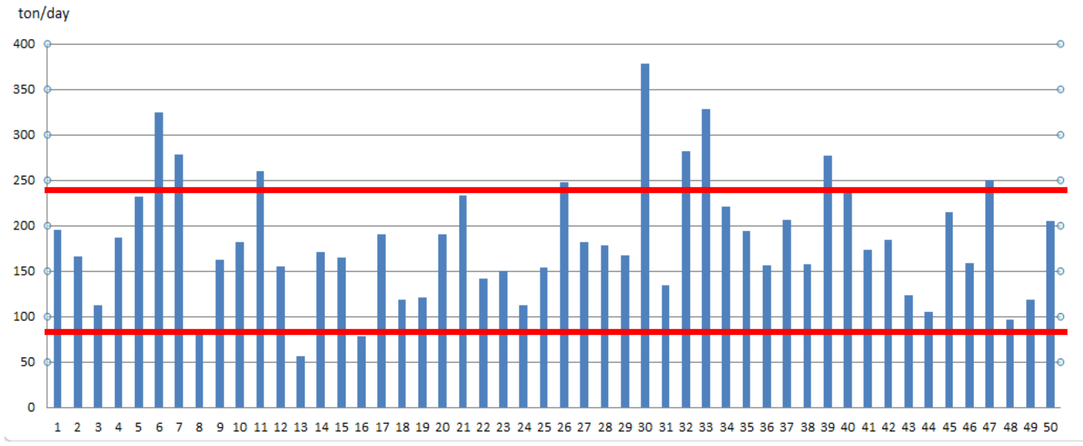

Figure 4.1 Daily Average Waste Collection from all Fifty Districts of BMA

The daily amount of municipal waste data were collected at three transfer station sites, from figure above can be separated into three ranges, first range from waste collected amount 100 tons/day or under or low waste generate rate, second range is from 100 tons reached to 250 tons/day of waste generation rate or a middle waste generation rate. The third range is from 250 tons/day to above or high range waste generation rate. Figure 4.2-4.4 show the waste generation rate of districts at each transfer station site.

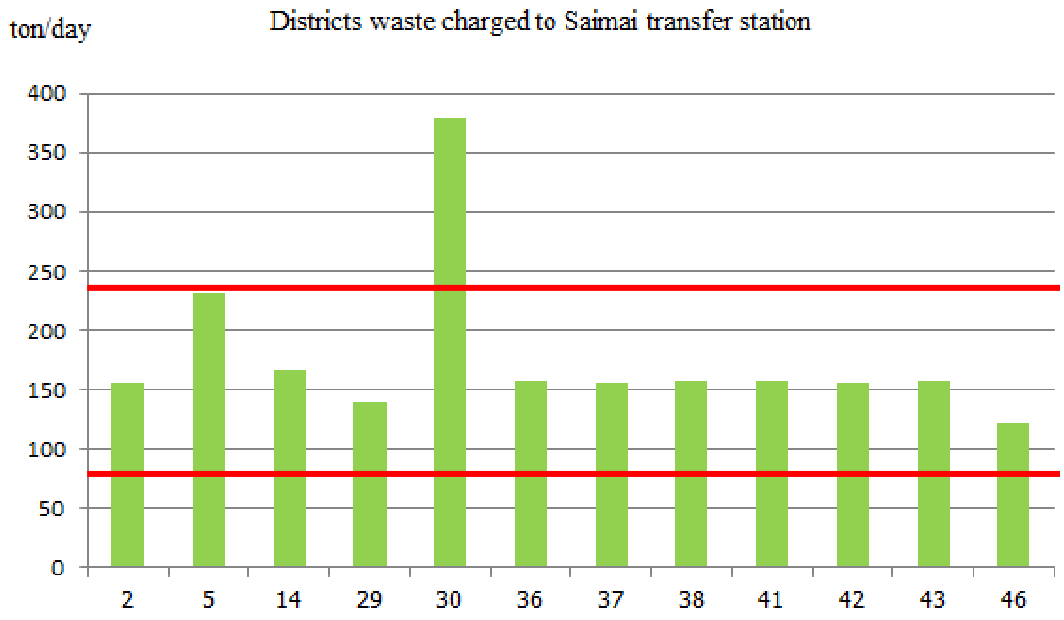

Figure 4.2 Waste Generation Rate of Districts at Saimai Transfer Station

Saimai transfer station received the waste from 12 districts as district 2 (Dusit) = 155.38 tons/day, district 5 (BangKhen) = 231.85 tons/day, district 14 (PayaThai) = 166.84 tons/day, district 29 (BangSue) = 140.23 tons/day, district 30 (Jatujak) = 378.58 tons/day, district 36 (DonMueang) = 156.51 tons/day, district 37 (Ratchathewi) = 155.85 tons/day, district 38 (LatPrao) = 157.74 tons/day, district 41 (LakSi) = 156.51 tons/day, district 42 (Saimai) = 155.85 tons/day, district 43 (KannaYao) = 157.74 tons/day, district 46 (KlongSamwa) = 122.12 tons/day, with and average of the total amount of 2,135.20 t/d. At this site, the data demonstrated that the waste generation rates of most districts are in the middle range, except Jatujak district which is in high range.

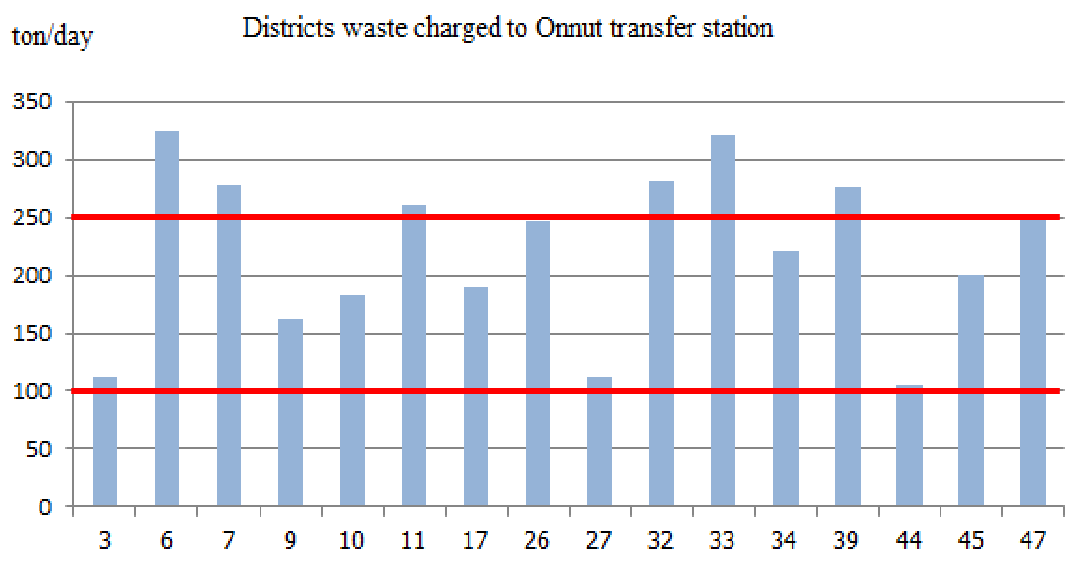

Figure 4.3 District Waste Charge to Onnut Transfer Station

Districts that contain waste to this the Saimai transfer station was 16 districts as district 3 (NongChok) = 111.93 tons/day, district 6 (BangKapi) = 324.82 tons/day, district 7 (PhathumWan) = 278.10 tons/day, district 9 (PraKaNong) = 162.18 tons/day, district 10 (MinBuri) = 182.41 tons/day, district 11 (Latkrabang) = 260.42 tons/day, district 17 (HuaiKwang) = 189.73 tons/day, district 26 (Dindang) = 247.42 tons/day, district 27 (Buengkum) = 112.06 tons/day, district 32 (Prawet) = 281.32 tons/day, district 33 (Klongtei) = 320.33 tons/day, district 34 (SuanLuang) = 220.79 tons/day, district 39 (Wattana) = 276.61 tons/day, district 44 (SapanSung) = 104.60 tons/day, district 45 (WangThongLang) = 200.47 tons/day, district 47 (Bangna) = 250.64 tons/day, summation of this all districts disposal to Onnut transfer station as 3,523.83 t/d. Figure show nearly half of the member of this group stand at the high range, example BangKapi, PhathumWan, Latkrabang, Prawet, Klongtei, Wattana and Bangna, the others at the middle range.

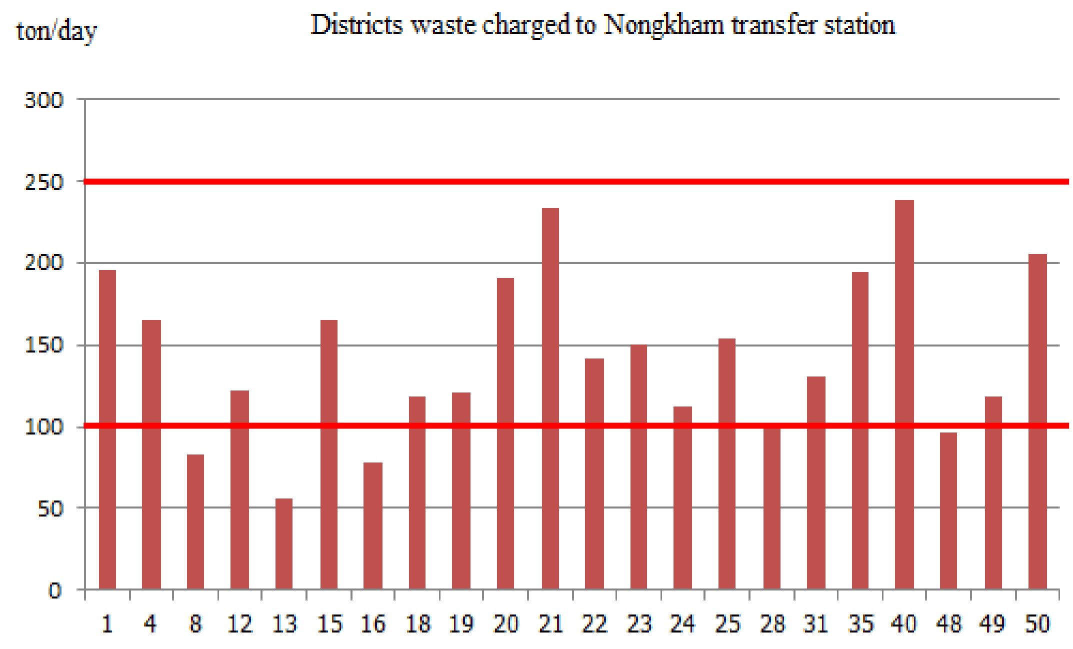

Figure 4.4 Districts Waste Charged to Nongkham Transfer Station

Districts that contain waste to this the Nongkham transfer station was 22 districts as district 1 (PraNakorn) = 195.87 tons/day, district 4 (BangRak) = 165.43 tons/day, district 8 (PomprabSattruPai) = 82.53 tons/day, district 12 (Yannawa) = 122.34 tons/day, district 13 (SumpanThawong) = 56.39 tons/day, district 15 (Thonburi) = 164.66 tons/day, district 16 (BangkokYai) = 77.71 tons/day, district 18 (KlongSan) = 118.78 tons/day, district 19 (TalingChan) = 121.23 tons/day, district 20 (BangkokNoi) = 190.35 tons/day, district 21 (BangkhunTien) = 233.31 tons/day, district 22 (PasiChaRoen) = 141.28 tons/day, district 23 (NongKham) = 149.56 tons/day, district 24 (Rattburana) = 112.16 t/d, district 25 (Bangplat) = 153.62 tons/day, district 28 (Sathorn) = 98.30 tons/day, district 31 (BangKhoLaem) = 130.51 tons/day, district 35 (JomThong) = 194.49 tons/day, district 40 (BangKhae) = 238.45

tons/day, district 48 (ThawiWatthana) = 96.8 tons/day, district 49 (Thungkru) = 118.55 tons/day, district 50 (Bangbon) = 204.85 t/d, total amount of waste discharged to this Nongkham transfer station by averages as 2,135.20 t/d. In this transfer station had no high range position but some low range districts shown as PomprabSattruPai, SumpanThawong, BangkokYai, Sathorn and ThawiWatthana, others stand in the middle range. Districts in Bangkok divined by high, middle and low range waste generation as figure below.

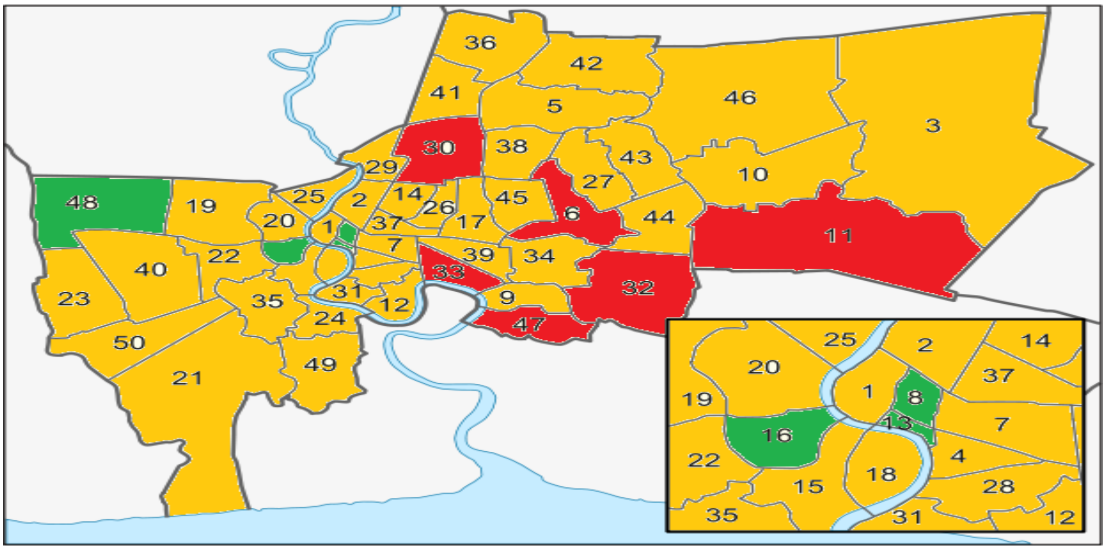

Figure 4.5 Waste Generation Range by District

Figure 4.5 demonstrated that the district number 6 (BangKapi), 11 (Latkrabang), 30 (Jatujak), 32 (Prawet), 33 (Klongtei) and 47 (Bangna) were in a high waste generation range (red color) of more than 250 tons/day waste. District number 8 (PomprabSattruPai), 13 (SumpanThawong), 16 (BangkokYai) and 48 (ThawiWatthana) were in a low waste generation range below 100 t/d (green color).

In addition, there have some districts that overlapping between two transfer stations such as district number 17 (HuaiKwang), 27 (Bungkum), 45 (WangThongLang) charged into Saimai transfer station, district number 4 (Bangrak), 12 (Yannawa), 14 (PayaThai), 28 (Sathorn), 31 (BangKhoLaem), 37 (Ratchathewi), 43 (KannaYao), 46 (KlongSamwa) charged into Onnut transfer station and district number 2 (Dusit), 29 (BangSue), 33 (Klongtei) charged into Nongkham transfer station. These numbers of districts overlapped made amount of site load went to a little higher. For the period of data that recorded (1st March 2014 to 7th March 2014) the Saimai transfer station site load was added by 84.46 t/d, Onnut transfer station load was added by 249.12 t/d and Nongkham transfer station load was added by 43.94 t/d.

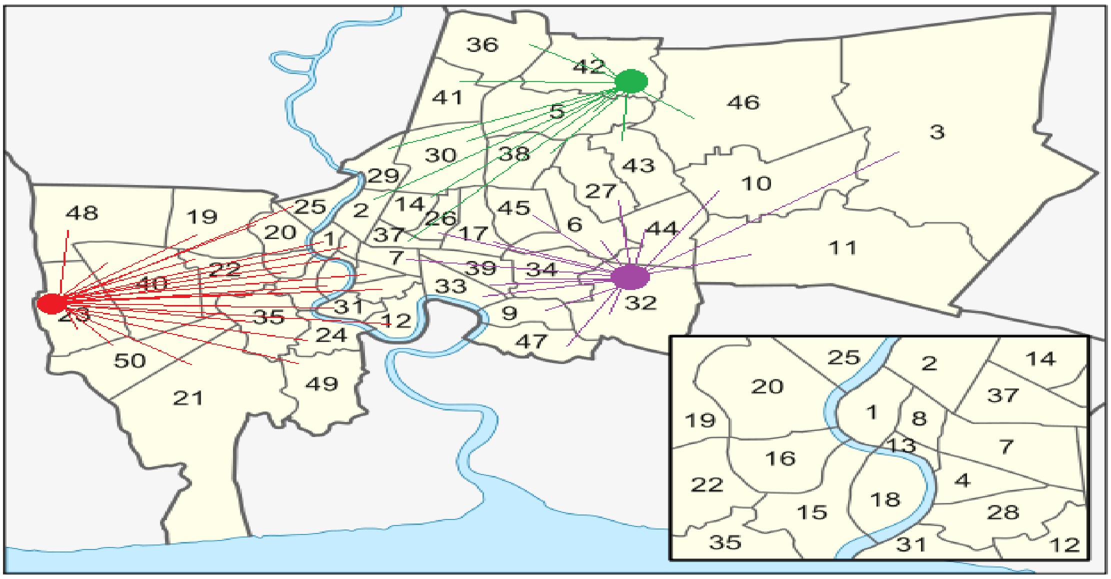

Figure 4.6 Responsible Area of Three Transfer Stations

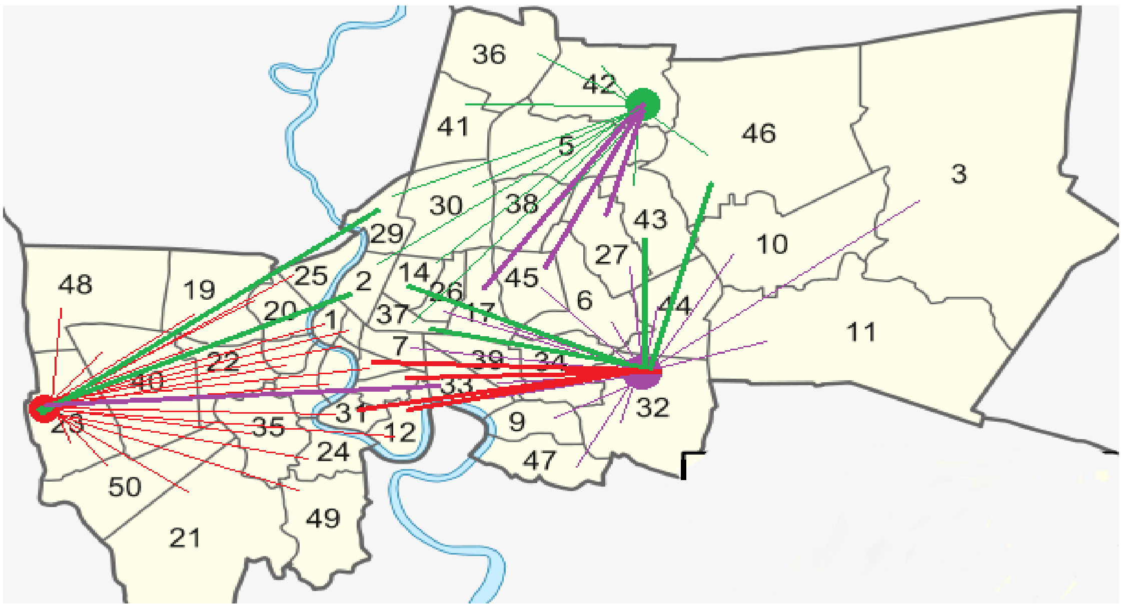

Figure 4.7 Overlapping Area

From data gathered data from 1st March 2014 to 7th March 2014, it was founded that the overlapping behavior was unpredictable.

From the BMA waste collection data from year 2005 to 2012, the total waste collection was increased every year as shown in Figure 4.8. Espeacially, from year 2011 (3,264.23 tons/day) to 2012 (3,567.67 tons/day), this change was 9.29 percent increase. Daily average of waste collection is shown in Figure 4.9

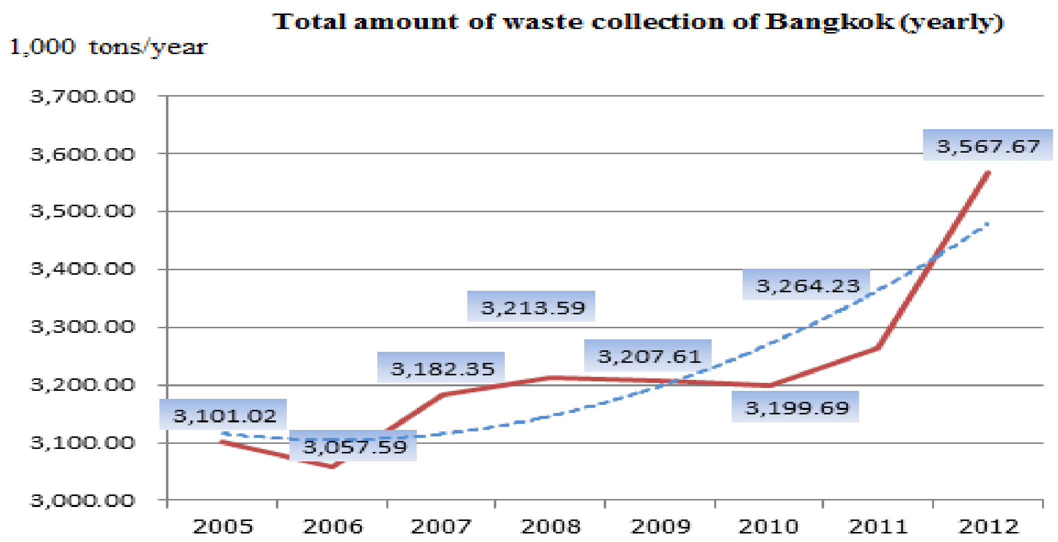

Figure 4.8 Total Amount of Waste Collection of the BMA(Yearly)

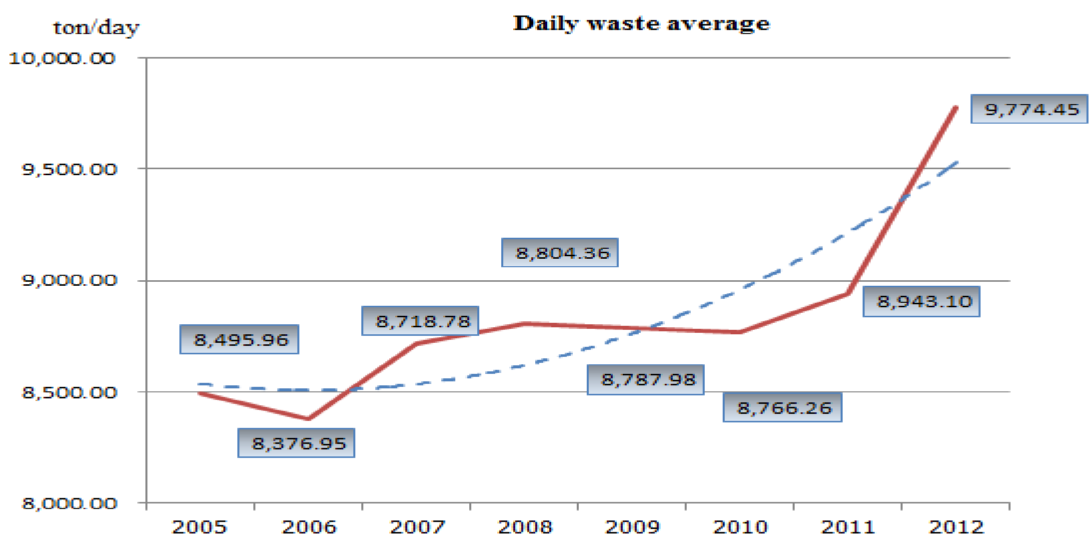

Figure 4.9 Daily Average of Waste Collection

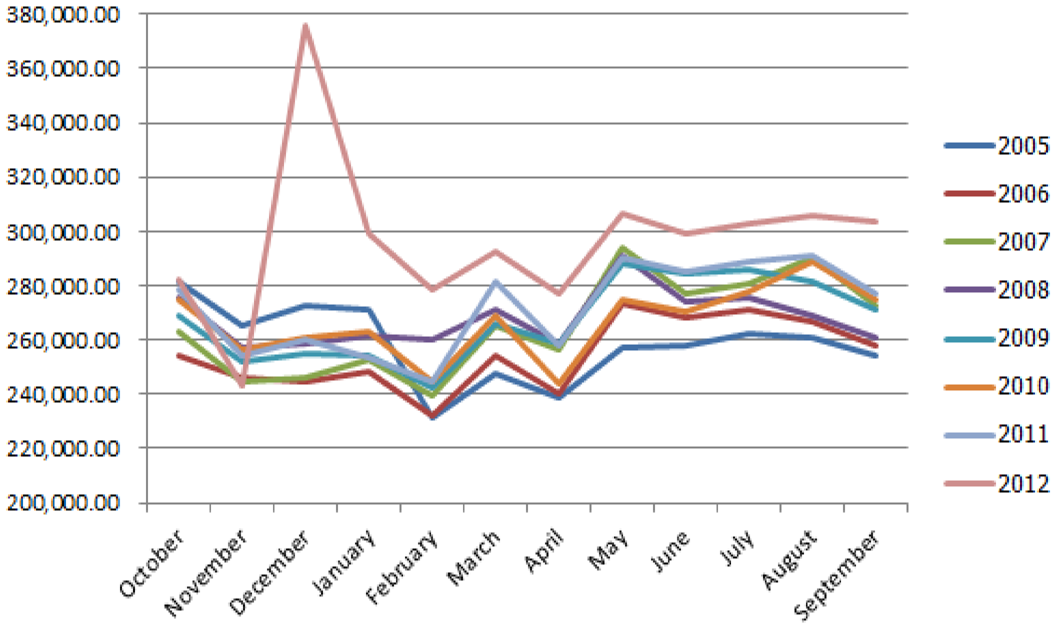

Figure 4.10 Monthly Waste Generation Rate

As can be seen from Figure 4.10, waste generation rate is vary from month ot month due to seasonal change. It was increased from February until August, then continually decreased to the lowest point in February. These changes related to the fruit production period and rainy season, which increase the weight of the collected waste. Also, in the year 2012, Bangkok faced with a great flood in October and November and two transfer stations were shut down. During this period, the monthly average of the collected waste was only 240,000 tons/month. In December 2011 to January 2012, the average monthly rate then increased to the highest of 380,000 tons/ month.

Waste composition of BMA is highly biodegradable, especially from the food waste. The common waste compositions of the BMA include paper, plastic, metal, glass as shown in Figure 4.11

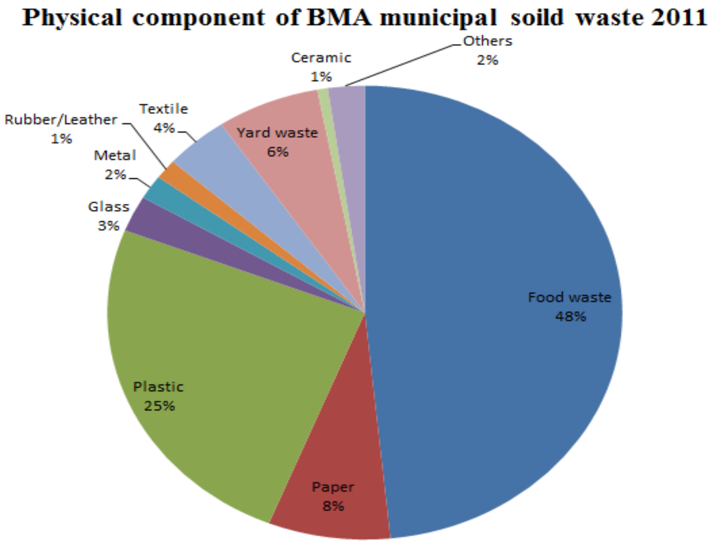

Figure 4.11 Waste Composition of BMA in year 2011

Source: Nakayama et al. (2013).

Waste composition of the BMA waste between 2007 and 2011 were demonstrated in the Table 4.1. From Table 4.1, presenting the significant percentage change in waste generation composition. Plastic component was the first position had a significant change at almost 14 percent from 2007. In contrast, almost other component were decreases because of the increased utilization of substituted by plastic materials. The increase of plastc composition could affect a routine management of the BMA in the near future.

Table 4.1 Waste Component Compare between 2007 and 2011

Waste Type	2007 (%)	2011 (%)	Change
Food waste	43	48.41	5.41
Paper	12.1	7.67	-4.43
Plastic	10.9	24.83	13.93
Glass	6.6	2.56	-4.04
Metal	3.5	1.72	-1.78
Rubber/Leather	2.6	1.40	-1.20
Textile	4.7	3.99	-0.71
Yard waste	6.9	6.46	-0.44

Table 4.1 (Continued)

Waste Type	2007 (%)	2011 (%)	Change
Ceramic	3.9	0.65	-3.25
Others	5.8	2.31	-3.49
Total	100	100	

Source: Nakayama et al. (2013).

4.2 Challenges of the BMA

For the challenges of BMA, researcher using in depth interview for gathering data and defining BMA challenges and problems in processes of municipal waste management system. Interviewer included Mrs. Suwanna Jungrungrueang the Deputy Director of BMA's department of Environment, Mr. Chatree Wattanakejorn the Director of Solid Waste Division, Mr. Panuwat Onthet the Analist of Policy and Planning Division, Mr. Pakphoom Phongklay the Engineering of Solid waste Division, Director of Onnut transfer station, Director of Nongkham Transfer station, Director of Saimai transfer station and Mr. Chaiyod Sasomsup the Director of Group 79 Co.,Ltd. In addition, researcher request for relating information, statistics, documents from interviewer. After analyzing gathered data including interview conclusion the results leading to clearly problems of BMA's waste transfer system as the overlapping waste transfer route. This research is based on the need to find out the real problems that arise in Bangkok's solid waste management system, which is an invisible problem of superficial understanding. First of all, there should be an in-depth understanding of Bangkok's solid waste management system. Thus research was conducted on the basis of space to observe, interview and ask for information to make the problems clearer.

The researcher took time to meet the director of the Environment Agency of the Bangkok Metropolitan Administration (BMA) and the Director of Refuse Disposal Division to inquire about the management issues and to visit the three main solid waste collection centers namely Bangkhen, Onnut and Nongkhaem. The researcher visited the three solid waste disposal sites several times to understand the solid waste disposal system better. Firstly, the waste trucks from various areas in Bangkok came to the center to remove solid waste from the center to the landfill. At the landfill area, the researcher made request to visit the management system, but due to safety restrictions, the company was not allowed to visit the site.

However, under the control of the Bangkok Metropolitan Administration, the researcher received good cooperation. Turning now to the management problems, firstly, the researcher founded there was an overlap of the solid waste transportation system to all waste disposal stations. The Bangkok metropolitan area consists of fifty administrative districts, so the garbage collectors are sent to each of these. When the truck arrives at the station, it must be weighed before entering the yard and then again after leaving the yard. According to the report, there should not be any abnormalities. That is, the use of overlapping paths by scattered frequencies.

The problem is that the Bangkok transportation planning system has not been modified, revised or reviewed. It was originally designated as a member of the various stations, but there were too many trucks assigned to the wrong stations, and the resulting overlap resulted in additional costs for the solid waste management system. When the researcher first became aware of this problem, the researcher asked questions about the obvious overlaps: ‘How were the different transportation systems to different stations organized and how much budget could be saved by more efficient organization? This was the first source of this research question.

In Bangkok, Rajchavipa Sub-Station was handles about 700 tons of solid waste a day. Research on this Rajchavipa Station by BMA indicates that a number of districts use to this station. The researcher wanted to find out if using other methods to decide how to operate the system would result in the same or different answer.

The most important aspect of this research is the study of the future of solid waste management in Bangkok, because Bangkok is an area in which many unusual events occur, such as political events, festivals, ceremonies or even emergencies such as floods. These can all contribute to the increase of solid waste in the short term, which sometimes exceeds the local capacity of handling that waste in some district. There should be a plan for emergency situations. At least some of the approaches to management can be useful in planning for the future.

4.3 Model Development

Transportation processes of municipal solid waste of the BMA can be illustrated using a graph-based model using three related nodes. The first node represents each district office of the BMA handle waste collection in their responsive area. The second node is a transfer station node that act as the center for waste collection vehicles to process their collected waste before transport the waste to landfill sites or the last node. BMA has three transfer stations, i.e., Saimai, Onnut and Nongkham sites. There is a composting plant at Onnut site. The last node is landfill site which is the final disposal process of the waste management. The landfill site are at NakornPathom and Chachengsao provinces, which is nearby Bangkok.

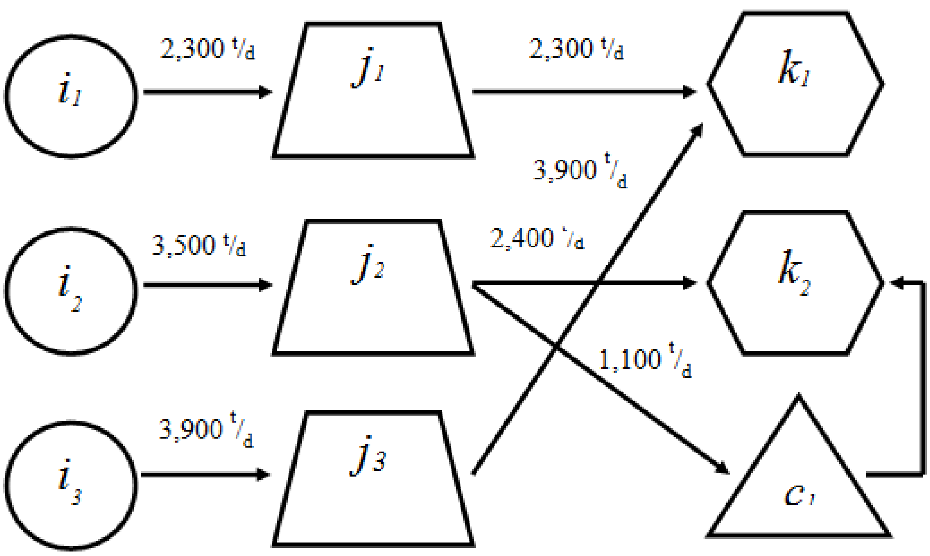

Figure 4.12 The Present Operation of BMA's Municipal Waste Management Processes

From the Figure 4.12, members of the processes included node *i* from group of districts in their responsive area for example, node i_1 have district number 2, 5, 14, 29, 30, 36, 37, 38, 41, 42, 43, 46 as members of node, i_2 have district number 3, 6, 7, 9, 10, 11, 17, 26, 27, 32, 33, 34, 39, 44, 45, 47 as members of node and i_3 have district number 1, 4, 8, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 28, 31, 35, 40, 48, 49, 50 as members. Node *j* represents transfer station as j_1 is Saimai transfer station, j_2 is Onnut transfer station and j_3 is Nongkham transfer station. From collection node (node *i*) waste transfer to the transfer station at transfer node (node *j*) then contain to land fill node as node *k* by k_1 at NakornPhaThom landfill and k_2 at Chachengsao landfill, these two landfill node operate by private company. In addition, node c_1 in the figure above is composting plant. The composting plant, which operating at Onnut transfer station area. Capacity of each node as presenting in the figure as node i_1 2,300 tons/day, i_2 3,500 tons/day, i_3 3,900 tons/day, j_1 2,300 tons/day, j_2 3,500 tons/day, j_3 3,900 tons/day, k_1 6,200 tons/day, k_2 2,400 tons/day, c_1 1,100 tons/day.

In the future, BMA's municipal waste management processes will be adjusted due to many reason for example, urbanization, population density and achieving the center of ASEAN country destination. These factors force the BMA to improve their waste management processes by create the new transfer station and invest in new equipment at transfer station sites. Operation processes in the future is shown in Figure 4.13.

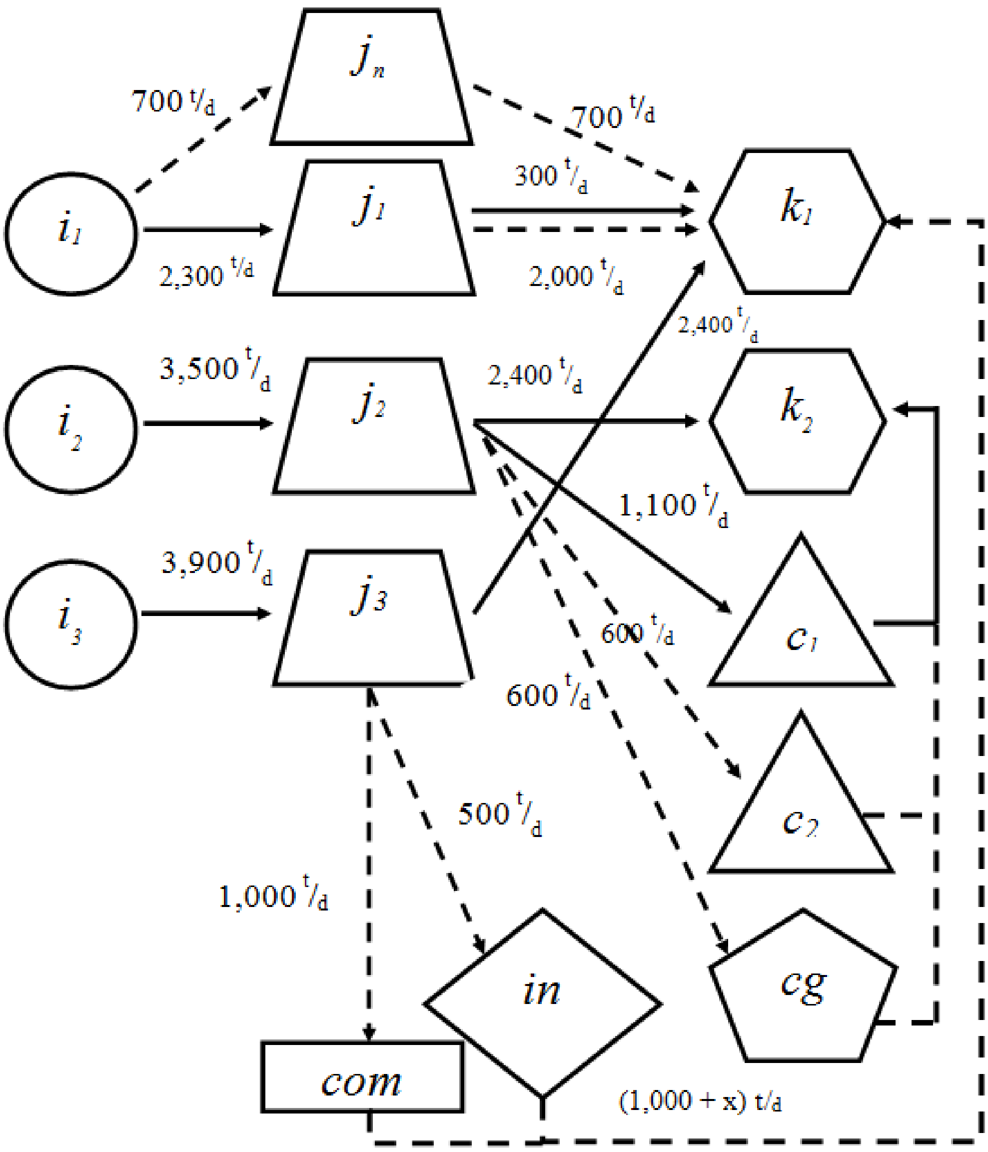

Figure 4.13 The Future Operation of BMA's Municipal Waste Management Processes

As can be seen from the Figure 4.13, the future operation process of BMA municipal management wwill more complicating than the present. There are 2,000 tons/day compacting machine at Saimai transfer station, a 500 tons/day incinerator and 1,000 tons/day compacting machine at Nongkham transfer station. In addition, other improvements are in construction or under procurement processes that includ new transfer station (j_n) at Jatujak district with 700 tons/day compacting machine, and the new composting plant (c_2) and compo-gas plant (*cg*) in Onnut transfer station.

The municipal waste management system has been improved to waste collection potential and reduce waste accumulation at the transfer station sites. The new transfer station at Jatujak district was pointed to create, because at Jatujak district has the most quantities of waste generation rate for over 350 tons/day. BMA is also interested in the waste to energy scheme, thus they allowed a private company to invest in 500 tons/day incinerator at Nongkham transfer station. This incinerator can produce an electricity over 5,000,000 watts with 20 years permission agreement.

4.4 Results

Due to the complexity of municipal waste management processes of BMA as presented, the new transfer station at Jatujak district (Ratchavipa sub-station) is now developed. It is important to properly rearrang the members of node i_1, i_2 and i_3 in order to optimize the waste amount input to all transfer stations at Ratchavipa, Saimai, Onnut and Nongkham. This new arrangement will definitely affect whole operation system. In addition, the problem of overlapping area as shown in figure 4.14 should be accounted by this new arrangement. A graph-based model of the new arrangement is shown in Figure 4.14.

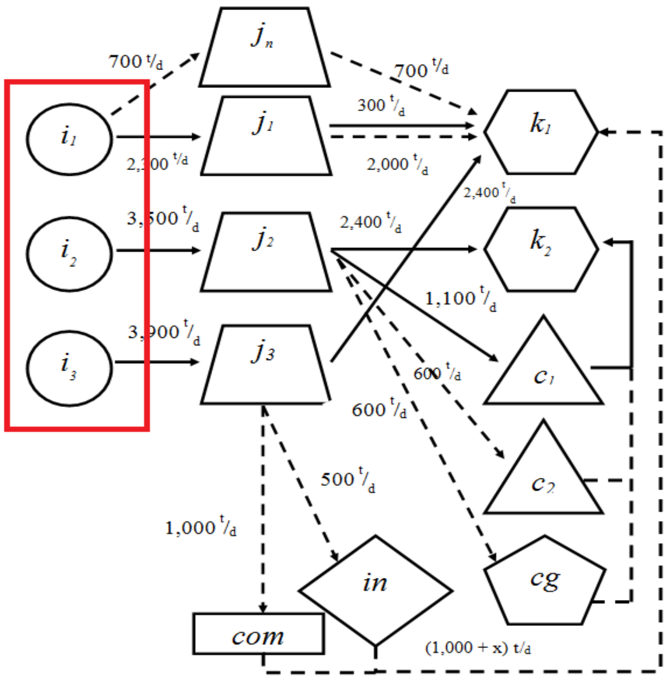

Figure 4.14 Arrangement of Collection Nodes

4.4.1 Present Transportation Cost of BMA

The amount of waste generated in each area will be collected and transported to the transfer station. In some areas, the collected waste is divided and transported to more than one transfer. For example, at Dusit district, the amount of waste were collected and transported to Saimai and NongKhame transfer station, or at Bang Rak district, the collected waste were transported to On-Nut transfer station and Nong Khaem transfer stations. Table 1 shows the waste transfer cost of the 50 districts. The cost formulation is as follows:

The waste transfer = The average distance from the district to the transfer station x Travel fuel loss (1.5) x Travel to and from (2) x Index of end Fuel consumption/liter/ton/ton (0.144) x Average daily amount of waste (Applied from Kingmongkut's University of Technology North Bangkok, 2015)

Table 4.2 Demonstrated Distance between Districts and Transfer Station

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)
Pra Nakorn	197.45	30.90	28.30	27.00
Dusit	173.86	27.20	26.50	25.90
Nong Chok	119.12	34.10	30.30	85.20
Bang Rak	170.78	32.60	31.90	25.70
Bang Khen	270.45	10.60	27.70	44.30
Bang Kapi	313.18	20.70	14.80	44.70
Phathum Wan	287.27	27.50	26.70	27.30
Pomprab Sattru Pai	86.46	29.40	26.80	29.20
Pra Ka Nong	149.99	24.80	12.00	41.20
Min Buri	191.42	19.00	19.10	74.00
Ladkrabang	255.50	37.90	12.90	70.50
Yannawa	183.85	32.20	31.50	28.70
Sumpan Thawong	58.51	31.80	31.00	25.90
Paya Thai	161.96	22.20	24.60	33.00
Thonburi	164.12	37.70	37.00	16.80
Bangkok Yai	85.92	38.00	41.00	20.60

Table 4.2 (Continued)

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)
Huai Kwang	197.60	18.90	21.60	41.60
Klongsan	134.02	35.20	33.20	19.30
Taling Chan	133.33	38.50	37.80	20.80
Bangkok Noi	202.02	35.50	33.60	26.20
Bang Khun Tien	289.36	53.10	49.10	18.60
Pasi Charoen	167.86	42.70	42.00	11.90
Nong Kham	173.49	60.90	60.10	8.60
Ratburana	116.91	40.80	39.00	25.80
Bangplat	152.03	29.80	39.40	27.90
Dindang	268.17	24.30	21.70	37.50
Buengkum	187.79	17.20	16.60	55.50
Sathorn	180.81	34.30	33.60	26.20
Bang sue	158.82	24.20	28.70	32.10
Jatujak	377.93	22.00	31.30	40.30
Bang kolaem	139.17	36.60	35.90	24.80
Prawet	270.84	24.20	2.50	52.10
Klongtei	339.42	26.20	14.10	34.70
Suanluang	237.62	25.30	10.40	50.00
Jom Thong	206.39	42.90	40.90	24.00
Don Mueang	184.60	16.00	32.90	49.10
Ratchathewi	202.58	24.80	23.10	31.40
Lat Prao	178.94	12.80	24.40	46.40
Wattana	287.42	21.20	17.00	42.20
Bangkae	271.63	47.50	52.50	11.70
Laksi	156.49	11.70	28.60	43.20
Saimai	197.01	0.45	26.30	56.60
Kanna Yao	130.28	15.70	13.60	60.10
Sapan Sung	118.16	19.20	14.10	56.50
Wangthong Lang	213.47	15.20	16.40	46.80
Klong Samwa	177.84	12.30	23.10	59.90
Bangna	221.44	27.60	22.30	38.60
Thawi Wattana	103.31	53.60	52.80	11.00

Table 4.2 (Continued)

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)
Thungkru	115.12	45.50	34.10	32.10
Bangbon	211.20	54.60	56.10	14.70
Total amount	9,572.91			

Table 4.3 Demonstrated the Number of Cost per ton Waste Converted

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)
Pra Nakorn	197.45	400.46	366.77	349.92
Dusit	173.86	352.51	343.44	335.66
Nong Chok	119.12	441.94	392.69	1104.19
Bang Rak	170.78	422.50	413.42	333.07
Bang Khen	270.45	137.38	358.99	574.13
Bang Kapi	313.18	268.27	191.81	579.31
Phathum Wan	287.27	356.40	346.03	353.81
Pomprab Sattru Pai	86.46	381.02	347.33	378.43
Pra Ka Nong	149.99	321.41	155.52	533.95
Min Buri	191.42	246.24	247.54	959.04
Ladkrabang	255.50	491.18	167.18	913.68
Yannawa	183.85	417.31	408.24	371.95
Sumpan Thawong	58.51	412.13	401.76	335.66
Paya Thai	161.96	287.71	318.82	427.68
Thonburi	164.12	488.59	479.52	217.73
Bangkok Yai	85.92	492.48	531.36	266.98
Huai Kwang	197.60	244.94	279.94	539.14
Klongsan	134.02	456.19	430.27	250.13
Taling Chan	133.33	498.96	489.89	269.57
Bangkok Noi	202.02	460.08	435.46	339.55
Bang Khun Tien	289.36	688.18	636.34	241.06

Table 4.3 (Continued)

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)
Pasi Charoen	167.86	553.39	544.32	154.22
Nong Kham	173.49	789.26	778.90	111.46
Ratburana	116.91	528.77	505.44	334.37
Bangplat	152.03	386.21	510.62	361.58
Dindang	268.17	314.93	281.23	486.00
Buengkum	187.79	222.91	215.14	719.28
Sathorn	180.81	444.53	435.46	339.55
Bang sue	158.82	313.63	371.95	416.02
Jatujak	377.93	285.12	405.65	522.29
Bang kolaem	139.17	474.34	465.26	321.41
Prawet	270.84	313.63	32.40	675.22
Klongtei	339.42	339.55	182.74	449.71
Suanluang	237.62	327.89	134.78	648.00
Jom Thong	206.39	555.98	530.06	311.04
Don Mueang	184.60	207.36	426.38	636.34
Ratchathewi	202.58	321.41	299.38	406.94
Lat Prao	178.94	165.89	316.22	601.34
Wattana	287.42	274.75	220.32	546.91
Bangkae	271.63	615.89	680.40	151.63
Laksi	156.49	151.63	370.66	559.87
Saimai	197.01	5.83	340.85	733.54
Kanna Yao	130.28	203.47	176.26	778.90
Sapan Sung	118.16	248.83	182.74	732.24
Wangthong Lang	213.47	196.99	212.54	606.53
Klong Samwa	177.84	159.41	299.38	776.30
Bangna	221.44	357.70	289.01	500.26
Thawi Wattana	103.31	694.66	684.29	142.56
Thungkru	115.12	589.69	441.94	416.02
Bangbon	211.20	707.62	727.06	190.51
	9,572.91			

Table 4.4 Present BMA's Municipal Waste Transfer Cost

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	197.45	400.46	366.77	*349.92	69,091.70
Dusit	173.86	*352.51	343.44	**335.66	61,108.10
Nong Chok	119.12	441.94	*392.69	1104.19	46,777.23
Bang Rak	170.78	422.50	**413.42	*333.07	58,426.81
Bang Khen	270.45	*137.38	358.99	574.13	37,154.42
Bang Kapi	313.18	268.27	*191.81	579.31	60,071.06
Phathum Wan	287.27	356.40	*346.03	353.81	99,404.04
Pomprab Sattru Pai	86.46	381.02	347.33	*378.43	32,719.06
Pra Ka Nong	149.99	321.41	*155.52	533.95	23,326.44
Min Buri	191.42	246.24	*247.54	959.04	47,384.11
Ladkrabang	255.50	491.18	*167.18	913.68	42,714.49
Yannawa	183.85	417.31	**408.24	*371.95	69,773.43
Sumpan Thawong	58.51	412.13	401.76	*335.66	19,639.47
Paya Thai	161.96	*287.71	**318.82	427.68	46,704.33
Thonburi	164.12	488.59	479.52	*217.73	35,733.85
Bangkok Yai	85.92	492.48	531.36	*266.98	22,938.92
Huai Kwang	197.60	**244.94	*279.94	539.14	55,302.31
Klongsan	134.02	456.19	430.27	*250.13	33,522.42
Taling Chan	133.33	498.96	489.89	*269.57	35,941.77
Bangkok Noi	202.02	460.08	435.46	*339.55	68,595.89
Bang Khun Tien	289.36	688.18	636.34	*241.06	69,753.12
Pasi Charoen	167.86	553.39	544.32	*154.22	25,887.37
Nong Kham	173.49	789.26	778.90	*111.46	19,337.20
Ratburana	116.91	528.77	505.44	*334.37	39,091.20
Bangplat	152.03	386.21	510.62	*361.58	54,971.01
Dindang	268.17	314.93	*281.23	486.00	75,417.45
Buengkum	187.79	**222.91	*215.14	719.28	40,963.93
Sathorn	180.81	444.53	**435.46	*339.55	69,175.16

Table 4.4 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Bang sue	158.82	*313.63	371.95	**416.02	52,401.19
Jatujak	377.93	*285.12	405.65	522.29	107,755.40
Bang kolaem	139.17	474.34	**465.26	*321.41	45,285.17
Prawet	270.84	313.63	*32.40	675.22	8,775.22
Klongtei	339.42	339.55	*182.74	**449.71	64,028.20
Suanluang	237.62	327.89	*134.78	648.00	32,026.42
Jom Thong	206.39	555.98	530.06	*311.04	64,195.55
Don Mueang	184.60	*207.36	426.38	636.34	38,278.66
Ratchathewi	202.58	*321.41	**299.38	406.94	63,967.86
Lat Prao	178.94	*165.89	316.22	601.34	29,684.36
Wattana	287.42	274.75	*220.32	546.91	63,324.37
Bangkae	271.63	615.89	680.40	*151.63	41,187.26
Laksi	156.49	*151.63	370.66	559.87	23,728.58
Saimai	197.01	*5.83	340.85	733.54	1,148.57
Kanna Yao	130.28	*203.47	**176.26	778.90	26,074.88
Sapan Sung	118.16	248.83	*182.74	732.24	21,592.56
Wangthong Lang	213.47	**196.99	*212.54	606.53	45,158.47
Klong Samwa	177.84	*159.41	**299.38	776.30	34,097.10
Bangna	221.44	357.70	*289.01	500.26	63,998.37
Thawi Wattana	103.31	694.66	684.29	*142.56	14,727.87
Thungkru	115.12	589.69	441.94	*416.02	47,892.22
Bangbon	211.20	707.62	727.06	*190.51	40,235.71
	9,572.91				2,290,490.27

Note: *=main,**=support

Table 4.4 shows the BMA's Municipal Waste Transfer Cost (under this research constraints) Some districts have sent their waste to more than one transfer station, * is used to mark as a main transfer station, while ** is used to mark as a support transfer station.

Based on the calculations, it is estimated that in 2015, the total cost of waste transfer of BMA was 2,290,490.27 baht per day or 836,028,948.55 baht per year.

From Table 4.4, it can be seen that some districts were not chosen the shortest route to the transfer station. This situation could lead to higher waste transfer cost. Table 4.5 shows the members of node *j* that is rearranged by the shortest distance to the transfer station.

Table 4.5 BMA's Districts Member Rearrange with Shortest Distance to Transfer Station

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
Dusit	163.22	Nong Chok	119.12	Pra Nakorn	197.45
Bang Khen	270.45	Bang Rak	19.23	Dusit	10.64
Paya Thai	158.53	Bang Kapi	313.18	Bang Rak	151.55
Huai Kwang	0.40	Phathum Wan	287.27	Pomprab Sattru Pai	86.46
Buengkum	72.43	Pra Ka Nong	149.99	Yannawa	145.54
Bang Sue	133.52	Min Buri	191.42	Sumpan Thawong	58.51
Jatujak	377.93	Ladkrabang	255.50	Thonburi	164.12
Don Mueang	184.60	Yannawa	38.31	Bangkok Yai	85.92
Ratchathewi	150.68	Paya Thai	3.43	Klong San	134.02
Lat Prao	178.94	Huai Kwang	197.20	Taling Chan	133.33
Lak Si	156.49	Dindang	268.17	Bangkok Noi	202.02
Saimai	197.01	Buengkum	115.36	Bang Khun Tien	289.36
Kanna Yao	114.36	Sathorn	81.13	Pasi Cha Roen	167.86
Wang Thong Lang	13.66	Bang Kho Laem	3.86	Nong Kham	173.49
Klong Samwa	136.78	Prawet	270.84	Ratburana	116.91
		Klongtei	331.92	Bangplat	152.03
		Suan Luang	237.62	Sathorn	99.68
		Rachathewi	51.90	Bangsue	25.30
		Wattana	287.42	Bang Kho Laem	135.31
		Kanna Yao	15.92	Klongtei	7.50
		Sapan Sung	118.16	Jom Thong	206.39

Table 4.5 (Continued)

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
		Wang Thong Lang	199.81	Bang Khae	271.63
		Klong Samwa	41.06	Thawi Wattana	103.31
		Bangna	221.44	Thungkru	115.12
				Bangbon	211.20
15	2,309.00	24	3,819.26	25	3,444.65
	[9.00]		[319.26]		(455.35)
				Total	9,572.91

As can be seen, from Table 4.5, Saimai transfer station has fifteen districts as members with the total amount received 2,309 tons per day, The Onnut transfer station has twenty four districts as members with total amount of collected waste of 3,819.26 tons a day, For Nongkham has twenty five districts members and 3,444.65 tons per day. There were fourteen districts with overlapping problem. Again, the capacities of each transfer station are, Saimai = 2,300 tons per day, Onnut = 3,500 tons per day and Nong Kham = 3,900 tons as limitation. (Kingmongkut's University of Technology North Bangkok, 2015). Therefore, Saimai transfer station has 9 tons of waste cumulated everyday, and Onnut transfer station has 319.26 tons of waste cumulative every day, while Nong Kham transfer station has 455.35 tons lower than its capacity.

Event: 1 Present Tranfer Cost of BMA by VAM Calculations

The Vogel approximation method (VAM) was used to rearrange the members of each transfer in order to calculate an optimal transfer cost for the BMA. The result is shown in Table 4.6.

Table 4.6 Optimal Transfer Cost using VAM

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	197.45	400.46	366.77	*349.92	69,091.70
Dusit	173.86	352.51	*343.44	335.66	59,489.84
Nong Chok	119.12	441.94	*392.69	1104.19	46,777.23
Bang Rak	170.78	422.50	413.42	*333.07	56,881.69
Bang Khen	270.45	*137.38	358.99	574.13	37,154.42
Bang Kapi	313.18	268.27	*191.81	579.31	60,071.06
Phathum Wan	287.27	356.40	*346.03	353.81	101,639.00
Pomprab Sattru Pai	86.46	381.02	*347.33	**378.43	30,030.15
Pra Ka Nong	149.99	321.41	*155.52	533.95	23,326.44
Min Buri	191.42	*246.24	247.54	959.04	47,351.75
Ladkrabang	255.50	491.18	*167.18	913.68	42,714.49
Yannawa	183.85	417.31	408.24	*371.95	68,383.01
Sumpan Thawong	58.51	412.13	401.76	*335.66	19,639.47
Paya Thai	161.96	*287.71	318.82	427.68	46,597.51
Thonburi	164.12	488.59	479.52	*217.73	35,733.85
Bangkok Yai	85.92	492.48	531.36	*266.98	22,938.92
Huai Kwang	197.60	*244.94	279.94	539.14	48,400.14
Klongsan	134.02	456.19	430.27	*250.13	33,522.42
Taling Chan	133.33	498.96	489.89	*269.57	35,941.77
Bangkok Noi	202.02	460.08	435.46	*339.55	68,595.89
Bang Khun Tien	289.36	688.18	636.34	*241.06	69,753.12
Pasi Charoen	167.86	553.39	544.32	*154.22	25,887.37
Nong Kham	173.49	789.26	778.90	*111.46	19,337.20
Ratburana	116.91	528.77	505.44	*334.37	39,091.20
Bangplat	152.03	386.21	510.62	*361.58	54,971.01
Dindang	268.17	314.93	*281.23	486.00	75,417.45
Buengkum	187.79	**222.91	*215.14	719.28	40,401.14

Table 4.6 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Sathorn	180.81	*444.53	435.46	339.55	61,394.04
Bang sue	158.82	*313.63	371.95	416.02	49,810.72
Jatujak	377.93	*285.12	405.65	522.29	107,755.40
Bang kolaem	139.17	474.34	465.26	*321.41	44,730.63
Prawet	270.84	313.63	*32.40	675.22	8,775.22
Klongtei	339.42	339.55	*182.74	449.71	62,025.61
Suanluang	237.62	327.89	*134.78	648.00	32,026.42
Jom Thong	206.39	555.98	530.06	*311.04	64,195.55
Don Mueang	184.60	*207.36	426.38	636.34	38,278.66
Ratchathewi	202.58	321.41	*299.38	406.94	60,648.40
Lat Prao	178.94	*165.89	316.22	601.34	29,684.36
Wattana	287.42	274.75	*220.32	546.91	63,324.37
Bangkae	271.63	615.89	680.40	*151.63	41,187.26
Laksi	156.49	*151.63	370.66	559.87	23,728.58
Saimai	197.01	*5.83	340.85	733.54	1,148.57
Kanna Yao	130.28	203.47	*176.26	778.90	22,963.15
Sapan Sung	118.16	248.83	*182.74	732.24	21,592.56
Wangthong Lang	213.47	*196.99	212.54	606.53	42,051.46
Klong Samwa	177.84	*159.41	299.38	776.30	28,349.47
Bangna	221.44	357.70	*289.01	500.26	63,998.37
Thawi Wattana	103.31	694.66	684.29	*142.56	14,727.87
Thungkru	115.12	589.69	441.94	*416.02	47,892.22
Bangbon	211.20	707.62	727.06	*190.51	40,235.71
Total	9,572.91				2,249,663.84

From the table above, waste transfer cost of the BMA after using VAM algorithm calculation was 2,249,663.84 baht per day, that was lower than the present cost 40,826.43 baht per day or 14,901,646.95 baht per year. As can be seen, table shows three group as with VAM calculation, Saimai transfer station has twelve district as members with collected waste of and amount received 2,300 tons per day.

Onnut transfer station has seventeen districts as members with collected waste of 3,500 tons per day and Nongkham transfer station has twenty three districts as members with collected waste of 3,772.91 tons per day. There were only two districts with overlapping problem. Saimai and Onnut transfer stations are operated at their full capacity, while Nongkham transfer station still has 127.0 tons more loading capacity.

As presented in Table 4.6 and 4.7 by using VAM optimizing calculation, the BMA's municipal waste management transportation route should be concern about rearrangement of transfer station as Event 1 example for economical reason.

Table 4.7 BMA's Districts Member Grouped with Transfer Station by VAM Technique

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer Station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
Bang Khen	270.45	Dusit	145.50	Pra Nakorn	197.45
Min Buri	24.89	Nong Chok	119.12	Dusit	28.36
Paya Thai	161.96	Bang Kapi	313.18	Bang Rak	170.78
Huai Kwang	197.60	Pomptan Sttru Pai	86.46	Phathum Wan	287.27
Bang Sue	158.82	Pra Ka Nong	149.99	Yannawa	183.85
Jatujak	377.93	Min Buri	166.53	Sumpan Thawong	58.51
Don Mueang	184.60	Ladkrabang	255.50	Thonburi	164.12
Lat Prao	178.94	Dindang	268.17	Bangkok Yai	85.92
Lak Si	156.49	Buengkum	187.79	Klong San	134.02
Saimai	197.01	Prawet	270.84	Taling Chan	133.33
Wang Thong Lang	213.47	Klongtei	339.42	Bangkok Noi	202.02
Klong Samwa	177.84	Suan Luang	237.62	Bang Khun Tien	289.36
		Rachathewi	202.58	Pasi Cha Roen	167.86
		Wattana	287.42	Nong Kham	173.49
		Kanna Yao	130.28	Ratburana	116.91
		Sapan Sung	118.16	Bangplat	152.03
		Bangna	221.44	Sathorn	180.81

Table 4.7 (Continued)

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer Station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
				Bang Kho Laem	139.17
				Jom Thong	206.39
				Bang Khae	271.63
				Thawi Wattana	103.31
				Thungkru	115.12
				Bangbon	211.20
12	2,300	17	3,500	23	3772.91
					(127.09)
				Total	9,572.91

4.4.2 Event 2: Ratchavipa Sub-Station Waste Transfer Cost

According to the MBA's master plan and Ratchavipa sub-station study report, BMA developed a new Ratchavipa sub-station to receive municipal waste from Jatujak, Dindang and BangSue districts with approximately 700 tons per day. When Ratchavipa sub-station starts its operation, the cost of BMA's municipal waste transfer system will be 2,120,401.82 baht per day, decreasing from the present cost (2,290,490.27 baht per day) by 170,088.45 baht per day or 62,082,284.25 per year.

Table 4.8 Distance from Districts to Ratchavipa Sub-Station

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer Station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)	Distance to Ratchavipa transfer sub-station (k.m.)
Pra Nakorn	197.45	30.90	28.30	27.00	17.4
Dusit	173.86	27.20	26.50	25.90	11.7
Nong Chok	119.12	34.10	30.30	85.20	37.9
Bang Rak	170.78	32.60	31.90	25.70	18.9
Bang Khen	270.45	10.60	27.70	44.30	7.7

Table 4.8 (Continued)

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer Station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)	Distance to Ratchavipa transfer sub-station (k.m.)
Bang Kapi	313.18	20.70	14.80	44.70	13.5
Phathum Wan	287.27	27.50	26.70	27.30	15
Pomprab Sattru Pai	86.46	29.40	26.80	29.20	14.6
Pra Ka Nong	149.99	24.80	12.00	41.20	19.6
Min Buri	191.42	19.00	19.10	74.00	22.8
Ladkrabang	255.50	37.90	12.90	70.50	44.9
Yannawa	183.85	32.20	31.50	28.70	20.2
Sumpan Thawong	58.51	31.80	31.00	25.90	18.1
Paya Thai	161.96	22.20	24.60	33.00	7.8
Thonburi	164.12	37.70	37.00	16.80	28.3
Bangkok Yai	85.92	38.00	41.00	20.60	29.8
Huai Kwang	197.60	18.90	21.60	41.60	8.7
Klongsan	134.02	35.20	33.20	19.30	21
Taling Chan	133.33	38.50	37.80	20.80	18.4
Bangkok Noi	202.02	35.50	33.60	26.20	16.4
Bang Khun Tien	289.36	53.10	49.10	18.60	40.3
Pasi Charoen	167.86	42.70	42.00	11.90	32.6
Nong Kham	173.49	60.90	60.10	8.60	39.4
Ratburana	116.91	40.80	39.00	25.80	27.8
Bangplat	152.03	29.80	39.40	27.90	10.9
Dindang	268.17	24.30	21.70	37.50	12.9
Buengkum	187.79	17.20	16.60	55.50	17.3
Sathorn	180.81	34.30	33.60	26.20	21.2
Bang sue	158.82	24.20	28.70	32.10	7.7
Jatujak	377.93	22.00	31.30	40.30	1.3
Bang kolaem	139.17	36.60	35.90	24.80	22.9

Table 4.8 (Continued)

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer station (k.m.)	Distance to Onnut Transfer Station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)	Distance to Ratchavipa transfer sub-station (k.m.)
Prawet	270.84	24.20	2.50	52.10	26.6
Klongtei	339.42	26.20	14.10	34.70	20.6
Suanluang	237.62	25.30	10.40	50.00	20.1
Jom Thong	206.39	42.90	40.90	24.00	29.8
Don Mueang	184.60	16.00	32.90	49.10	14.3
Ratchathewi	202.58	24.80	23.10	31.40	13.4
Lat Prao	178.94	12.80	24.40	46.40	9.8
Wattana	287.42	21.20	17.00	42.20	15.2
Bangkae	271.63	47.50	52.50	11.70	37.4
Laksi	156.49	11.70	28.60	43.20	12.9
Saimai	197.01	0.45	26.30	56.60	24.6
Kanna Yao	130.28	15.70	13.60	60.10	19.1
Sapan Sung	118.16	19.20	14.10	56.50	19.3
Wangthong Lang	213.47	15.20	16.40	46.80	10.2
Klong Samwa	177.84	12.30	23.10	59.90	23.4
Bangna	221.44	27.60	22.30	38.60	22.7
Thawi Wattana	103.31	53.60	52.80	11.00	33.5
Thungkru	115.12	45.50	34.10	32.10	33.5
Bangbon	211.20	54.60	56.10	14.70	45.5
Total amount	9,572.91				

Table 4.9 Cost of Transfer from Districts to Ratchavipa Sub-Station

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer sub-Station (baht/ton)
Pra Nakorn	197.45	400.46	366.77	349.92	225.50
Dusit	173.86	352.51	343.44	335.66	151.63
Nong Chok	119.12	441.94	392.69	1104.19	491.18
Bang Rak	170.78	422.50	413.42	333.07	244.94
Bang Khen	270.45	137.38	358.99	574.13	99.79
Bang Kapi	313.18	268.27	191.81	579.31	174.96
Phathum Wan	287.27	356.40	346.03	353.81	194.40
Pomprab Sattru Pai	86.46	381.02	347.33	378.43	189.22
Pra Ka Nong	149.99	321.41	155.52	533.95	254.02
Min Buri	191.42	246.24	247.54	959.04	295.49
Ladkrabang	255.50	491.18	167.18	913.68	581.90
Yannawa	183.85	417.31	408.24	371.95	261.79
Sumpan Thawong	58.51	412.13	401.76	335.66	234.58
Paya Thai	161.96	287.71	318.82	427.68	101.09
Thonburi	164.12	488.59	479.52	217.73	366.77
Bangkok Yai	85.92	492.48	531.36	266.98	386.21
Huai Kwang	197.60	244.94	279.94	539.14	112.75
Klongsan	134.02	456.19	430.27	250.13	272.16
Taling Chan	133.33	498.96	489.89	269.57	238.46
Bangkok Noi	202.02	460.08	435.46	339.55	212.54
Bang Khun Tien	289.36	688.18	636.34	241.06	522.29
Pasi Charoen	167.86	553.39	544.32	154.22	422.50
Nong Kham	173.49	789.26	778.90	111.46	510.62
Ratburana	116.91	528.77	505.44	334.37	360.29
Bangplat	152.03	386.21	510.62	361.58	141.26

Table 4.9 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer sub-Station (baht/ton)
Dindang	268.17	314.93	281.23	486.00	167.18
Buengkum	187.79	222.91	215.14	719.28	224.21
Sathorn	180.81	444.53	435.46	339.55	274.75
Bang sue	158.82	313.63	371.95	416.02	99.79
Jatujak	377.93	285.12	405.65	522.29	16.85
Bang kolaem	139.17	474.34	465.26	321.41	296.78
Prawet	270.84	313.63	32.40	675.22	344.74
Klongtei	339.42	339.55	182.74	449.71	266.98
Suanluang	237.62	327.89	134.78	648.00	260.50
Jom Thong	206.39	555.98	530.06	311.04	386.21
Don Mueang	184.60	207.36	426.38	636.34	185.33
Ratchathewi	202.58	321.41	299.38	406.94	173.66
Lat Prao	178.94	165.89	316.22	601.34	127.01
Wattana	287.42	274.75	220.32	546.91	196.99
Bangkae	271.63	615.89	680.40	151.63	484.70
Laksi	156.49	151.63	370.66	559.87	167.18
Saimai	197.01	5.83	340.85	733.54	318.82
Kanna Yao	130.28	203.47	176.26	778.90	247.54
Sapan Sung	118.16	248.83	182.74	732.24	250.13
Wangthong Lang	213.47	196.99	212.54	606.53	132.19
Klong Samwa	177.84	159.41	299.38	776.30	303.26
Bangna	221.44	357.70	289.01	500.26	294.19
Thawi Wattana	103.31	694.66	684.29	142.56	434.16
Thungkru	115.12	589.69	441.94	416.02	434.16
Bangbon	211.20	707.62	727.06	190.51	589.68
	9,572.91				

Table 4.10 Transfer Cost of BMA's Municipal Waste after Using Ratchavipa Sub-Station

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer Sub-Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	197.45	400.46	366.77	*349.92	225.50	69,091.70
Dusit	173.86	*352.51	343.44	*335.66	151.63	61,108.10
Nong Chok	119.12	441.94	*392.69	1104.19	491.18	46,777.23
Bang Rak	170.78	422.50	**413.42	*333.07	244.94	58,426.81
Bang Khen	270.45	*137.38	358.99	574.13	99.79	37,154.42
Bang Kapi	313.18	268.27	*191.81	579.31	174.96	60,071.06
Phathum Wan	287.27	356.40	*346.03	353.81	194.40	99,404.04
Pomprab Sattru Pai	86.46	381.02	347.33	*378.43	189.22	32,719.06
Pra Ka Nong	149.99	321.41	*155.52	533.95	254.02	23,326.44
Min Buri	191.42	246.24	*247.54	959.04	295.49	47,384.11
Ladkrabang	255.50	491.18	*167.18	913.68	581.90	42,714.49
Yannawa	183.85	417.31	**408.24	*371.95	261.79	69,773.43
Sumpan Thawong	58.51	412.13	401.76	*335.66	234.58	19,639.47
Paya Thai	161.96	*287.71	**318.82	427.68	101.09	46,704.33
Thonburi	164.12	488.59	479.52	*217.73	366.77	35,733.85
Bangkok Yai	85.92	492.48	531.36	*266.98	386.21	22,938.92
Huai Kwang	197.60	**244.94	*279.94	539.14	112.75	55,302.31
Klongsan	134.02	456.19	430.27	*250.13	272.16	33,522.42
Taling Chan	133.33	498.96	489.89	*269.57	238.46	35,941.77
Bangkok Noi	202.02	460.08	435.46	*339.55	212.54	68,595.89
Bang Khun Tien	289.36	688.18	636.34	*241.06	522.29	69,753.12
Pasi Charoen	167.86	553.39	544.32	*154.22	422.50	25,887.37
Nong Kham	173.49	789.26	778.90	*111.46	510.62	19,337.20
Ratburana	116.91	528.77	505.44	*334.37	360.29	39,091.20
Bangplat	152.03	386.21	510.62	*361.58	141.26	54,971.01
Dindang	268.17	314.93	281.23	486.00	*167.18	44,832.66
Buengkum	187.79	**222.91	*215.14	719.28	224.21	40,963.93

Table 4.10 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer Sub-Station (baht/ton)	Cost of Transfer (bath/day)
Sathorn	180.81	444.53	*435.46	*339.55	274.75	69,175.16
Bang sue	158.82	313.63	371.95	416.02	*99.79	15,848.65
Jatujak	377.93	285.12	405.65	522.29	*16.85	4,804.27
Bang kolaem	139.17	474.34	*465.26	*321.41	296.78	45,285.17
Prawet	270.84	313.63	*32.40	675.22	344.74	8,775.22
Klongtei	339.42	339.55	*182.74	*449.71	266.98	64,028.20
Suanluang	237.62	327.89	*134.78	648.00	260.50	32,026.42
Jom Thong	206.39	555.98	530.06	*311.04	386.21	64,195.55
Don Mueang	184.60	207.36	426.38	636.34	185.33	38,278.66
Ratchathewi	202.58	*321.41	*299.38	406.94	173.66	63,967.86
Lat Prao	178.94	*165.89	316.22	601.34	127.01	29,684.36
Wattana	287.42	274.75	*220.32	546.91	196.99	63,324.37
Bangkae	271.63	615.89	680.40	*151.63	484.70	41,187.26
Laksi	156.49	*151.63	370.66	559.87	167.18	23,728.58
Saimai	197.01	*5.83	340.85	733.54	318.82	1,148.57
Kanna Yao	130.28	*203.47	*176.26	778.90	247.54	26,074.88
Sapan Sung	118.16	248.83	*182.74	732.24	250.13	21,592.56
Wangthong Lang	213.47	196.99	*212.54	606.53	132.19	45,158.47
Klong Samwa	177.84	*159.41	*299.38	776.30	303.26	34,097.10
Bangna	221.44	357.70	*289.01	500.26	294.19	63,998.37
Thawi Wattana	103.31	694.66	684.29	*142.56	434.16	14,727.87
Thungkru	115.12	589.69	441.94	*416.02	434.16	47,892.22
Bangbon	211.20	707.62	727.06	*190.51	589.68	40,235.71
Total	9,572.91					2,120,401.82

Table 4.11 Member of Each Transfer Station after Ratchavipa Operate

Saimai Transfer Station	Amount of Waste (tons/day)	Onnut Transfer station	Amount of Waste (tons/day)	Nongkham Transfer Station	Amount of Waste (tons/day)	Ratchavipa Sub-Station	Amount of Waste (tons/day)
Dusit	163.22	Nong Chok	119.12	Pra Nakorn	197.45	Bang Sue	158.82
Bang Khen	270.45	Bang Rak	19.23	Dusit	10.64	Jatujak	377.93
Paya Thai	158.53	Bang Kapi	313.18	Bang Rak	151.55	Dindang	268.17
Huai Kwang	0.40	Phathum Wan	287.27	Pomprab Sattru Pai	86.46		
Buengkum	72.43	Pra Ka Nong	149.99	Yannawa	145.54		
Don Mueang	184.60	Min Buri	191.42	Sumpan Thawong	58.51		
Ratchathewi	150.68	Ladkrabang	255.50	Thonburi	164.12		
Lat Prao	178.94	Yannawa	38.31	Bangkok Yai	85.92		
Lak Si	156.49	Paya Thai	3.43	Klong San	134.02		
Saimai	197.01	Huai Kwang	197.20	Taling Chan	133.33		
Kanna Yao	114.36	Buengkum	115.36	Bangkok Noi	202.02		
Wang Thong Lang	13.66	Sathorn	81.13	Bang Khun Tien	289.36		
Klong Samwa	136.78	Bang Kho Laem	3.86	Pasi Cha Roen	167.86		
		Prawet	270.84	Nong Kham	173.49		
		Klongtei	331.92	Ratburana	116.91		
		Suan Luang	237.62	Bangplat	152.03		
		Rachathewi	51.90	Sathorn	99.68		
		Wattana	287.42	Bang Kho Laem	135.31		
		Kanna Yao	15.92	Klongtei	7.50		
		Sapan Sung	118.16	Jom Thong	206.39		
		Wang Thong Lang	199.81	Bang Khae	271.63		
		Klong Samwa	41.06	Thawi Wattana	103.31		

Table 4.11 (Continued)

Saimai Transfer Station	Amount of Waste (tons/day)	Onnut Transfer station	Amount of Waste (tons/day)	Nongkham Transfer Station	Amount of Waste (tons/day)	Ratchavipa Sub-Station	Amount of Waste (tons/day)
		Bangna	221.44	Thungkru	115.12		
				Bangbon	211.20		
13	1,797.55 (502.45)	23	3,551.09 [51.09]	24	3,419.35 (480.65)	3	804.92 [104.92]
						Total	9,572.91

Table 4.11 shows, that Saimai transfer station have thirteen districts as members and amount received 1,797.55 tons per day, The Onnut transfer station has twenty three districts and amount received 3,551.09 tons a day, For Nongkham has twenty four districts members and 3,419.35 tons received and Ratchavipa has three districts as member received 804.92 tons a day, there was eleven districts overlapped. Nevertheless, from capacities of each transfer station aspect, Saimai was 2,300 tons per day, Onnut was 3,500 tons per day and Nong Kham was 3,900 tons and Ratchavipa was 700 tons as limitation. (Kingmongkut’s University of Technology North Bangkok, 2015) From the table above mean Saimai has 502.45 tons waste loading capacities. Onnut transfer station has 51.09 tons cumulative waste every day. Nong Kham transfer station has 480.65 tons more loading capacity and Ratchavipa has 104.92 tons cumulative waste every day.

Event 2: Ratchavipa Sub-Station Waste Transportation Cost by VAM Calculation

After use VAM technique calculate the result show as table below

Table 4.12 Cost of BMA's Waste Transfer by VAM Calculation

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer Sub-Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	197.45	400.46	366.77	*349.92	225.50	69,091.70
Dusit	173.86	*352.51	343.44	335.66	151.63	61,287.39
Nong Chok	119.12	441.94	*392.69	1104.19	491.18	46,777.23
Bang Rak	170.78	422.50	413.42	*333.07	244.94	56,881.69
Bang Khen	270.45	*137.38	358.99	574.13	99.79	37,154.42
Bang Kapi	313.18	268.27	*191.81	579.31	174.96	60,071.06
Phathum Wan	287.27	**356.40	*346.03	353.81	194.40	99,404.04
Pomprab Sattru Pai	86.46	381.02	*347.33	378.43	189.22	30,030.15
Pra Ka Nong	149.99	321.41	*155.52	533.95	254.02	23,326.44
Min Buri	191.42	*246.24	247.54	959.04	295.49	47,135.26
Ladkrabang	255.50	491.18	*167.18	913.68	581.90	42,714.49
Yannawa	183.85	417.31	408.24	*371.95	261.79	68,383.01
Sumpan Thawong	58.51	412.13	*401.76	335.66	234.58	23,506.98
Paya Thai	161.96	*287.71	318.82	427.68	**101.09	44,503.64
Thonburi	164.12	488.59	479.52	*217.73	366.77	35,733.85
Bangkok Yai	85.92	492.48	531.36	*266.98	386.21	22,938.92
Huai Kwang	197.60	*244.94	279.94	539.14	112.75	48,400.14
Klongsan	134.02	456.19	430.27	*250.13	272.16	33,522.42
Taling Chan	133.33	498.96	489.89	*269.57	238.46	35,941.77
Bangkok Noi	202.02	460.08	435.46	*339.55	212.54	68,595.89
Bang Khun Tien	289.36	688.18	636.34	*241.06	522.29	69,753.12
Pasi Charoen	167.86	553.39	544.32	*154.22	422.50	25,887.37
Nong Kham	173.49	789.26	778.90	*111.46	510.62	19,337.20
Ratburana	116.91	528.77	*505.44	334.37	360.29	59,090.99
Bangplat	152.03	386.21	510.62	361.58	*141.26	21,475.76
Dindang	268.17	314.93	*281.23	486.00	167.18	75,417.45
Buengkum	187.79	222.91	*215.14	719.28	224.21	40,401.14
Sathorn	180.81	444.53	435.46	*339.55	274.75	61,394.04
Bang sue	158.82	313.63	371.95	416.02	*99.79	15,848.65

Table 4.12 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer Sub-Station (baht/ton)	Cost of Transfer (bath/day)
Jatujak	377.93	285.12	405.65	522.29	*16.85	6,368.12
Bang kolaem	139.17	474.34	465.26	*321.41	296.78	44,730.63
Prawet	270.84	313.63	*32.40	675.22	344.74	8,775.22
Klongtei	339.42	339.55	*182.74	449.71	266.98	62,025.61
Suanluang	237.62	327.89	*134.78	648.00	260.50	32,026.42
Jom Thong	206.39	555.98	530.06	*311.04	386.21	64,195.55
Don Mueang	184.60	*207.36	426.38	636.34	185.33	38,278.66
Ratchathewi	202.58	*321.41	299.38	406.94	173.66	65,111.24
Lat Prao	178.94	*165.89	316.22	601.34	127.01	29,684.36
Wattana	287.42	274.75	*220.32	546.91	196.99	63,324.37
Bangkae	271.63	615.89	680.40	*151.63	484.70	41,187.26
Laksi	156.49	*151.63	370.66	559.87	167.18	23,728.58
Saimai	197.01	*5.83	340.85	733.54	318.82	1,148.57
Kanna Yao	130.28	203.47	*176.26	778.90	247.54	22,963.15
Sapan Sung	118.16	248.83	*182.74	732.24	250.13	21,592.56
Wangthong Lang	213.47	*196.99	212.54	606.53	132.19	42,051.46
Klong Samwa	177.84	*159.41	299.38	776.30	303.26	28,349.47
Bangna	221.44	357.70	*289.01	500.26	294.19	63,998.37
Thawi Wattana	103.31	694.66	684.29	*142.56	434.16	14,727.87
Thungkru	115.12	589.69	**441.94	*416.02	434.16	49,367.59
Bangbon	211.20	707.62	727.06	*190.51	589.68	40,235.71
Total	9,572.91					2,107,928.82

Note: *=main,**=support

Results from calculation suggested to renew group members of all transfer station as demonstrated in table and should be receive amount waste from Bangplat, Bang Sue, Jatujak and some of a part of waste from Paya Thai instead of Bang Sue, Dindang, Jatujak as in the BMA's plan of capacity usage of Ratchavipa sub-station.

The summation of cost by this calculation was 2,107,928.82 baht per day lower than results in table 4.12 that 2,120,401.82 baht per day by 12,473 baht per day or 4,552,645 baht a year.

Table 4.13 Members of Transfer Stations with VAM Calculated Results

Saimai Transfer station	Amount of Waste (tons/day)	Onnut Transfer station	Amount of Waste (tons/day)	Nongkham Transfer station	Amount of Waste (tons/day)	Ratchavipa Sub-Station	Amount of Waste (tons/day)
Dusit	173.86	Nong Chok	119.12	Pra Nakorn	197.45	Paya Thai	11.22
Bang Khen	270.45	Bang Kapi	313.18	Bang Rak	170.78	Bangplat	152.03
Phathum Wan	5	Phathum Wan	282.27	Yannawa	183.85	Bang Sue	158.82
Min Buri	191.42	Pomprab Sattru Pai	86.46	Thonburi	164.12	Jatujak	377.93
Paya Thai	150.74	Pra Ka Nong	149.99	Bangkok Yai	85.92		
Huai Kwang	197.60	Ladkrabang	255.50	Klong San	134.02		
Don Mueang	184.60	Sumpan Thawong	58.51	Taling Chan	133.33		
Ratchathewi	202.58	Ratburana	116.91	Bangkok Noi	202.02		
Lat Prao	178.94	Dindang	268.17	Bang Khun Tien	289.36		
Lak Si	156.49	Buengkum	187.79	Pasi Cha Roen	167.86		
Saimai	197.01	Prawet	270.84	Nong Kham	173.49		
Wang Thong Lang	213.47	Klongtei	339.42	Sathorn	180.81		
Klong Samwa	177.84	Suan Luang	237.62	Bang Kho Laem	139.17		
		Wattana	287.42	Jom Thong	206.39		
		Kanna Yao	130.28	Bang Khae	271.63		
		Sapan Sung	118.16	Thawi Wattana	103.31		
		Bangna	221.44	Thungkru	58.2		

Table 4.13 (Continued)

Saimai Transfer station	**Amount of Waste (tons/day)**	**Onnut Transfer station**	**Amount of Waste (tons/day)**	**Nongkham Transfer station**	**Amount of Waste (tons/day)**	**Ratchavipa Sub-Station**	**Amount of Waste (tons/day)**
		Thungkru	56.92	Bangbon	211.20		
13	2,300	18	3,500	18	3,072.91	4	700
					(827.09)		
						Total	9,572.91

From table above, calculation by full capacities constrain the VAM suggestion to choose Paya Thai, Bangplat, Bangsue and Jatujak districts instead Dindang, Bangsue and Jatujak.

4.4.3 Event 3: New Transfer Station

According to table 4.13 BMA's municipal waste transfer cost, as can be seen the most transfer cost from Jatujak about 107,755.40 baht per day, that is a reason for made BMA decided to create the new transfer station, the Rajchavipa sub-transfer station and after create the station transfer cost of Jatujak was decreased to 4,804.27 baht per day. From the same reason, Phathum Wan district was the second highest transfer cost at 99,404.61 baht per day. After BMA create Rajchavipa sub-station, waste transfer cost of Phathum Wan district is the highest at all. In nearly future Phathum Wan transferring cost will stand over a hundred thousand per day. In the same way as Jatujak, BMA should try to reduce waste transfer cost by create the new transfer station. The possibility area at Phathun Wan district probably was Hua Lamphong train station area. This area has potential and suitable. On west side of Hua lamphong train station have enough space for construct waste transfer station. In addition, two hundred meters form this area is Sirat express way that can connecting to Nongkham transfer station or heading to sanitary landfill at NakornPaThom province directly.

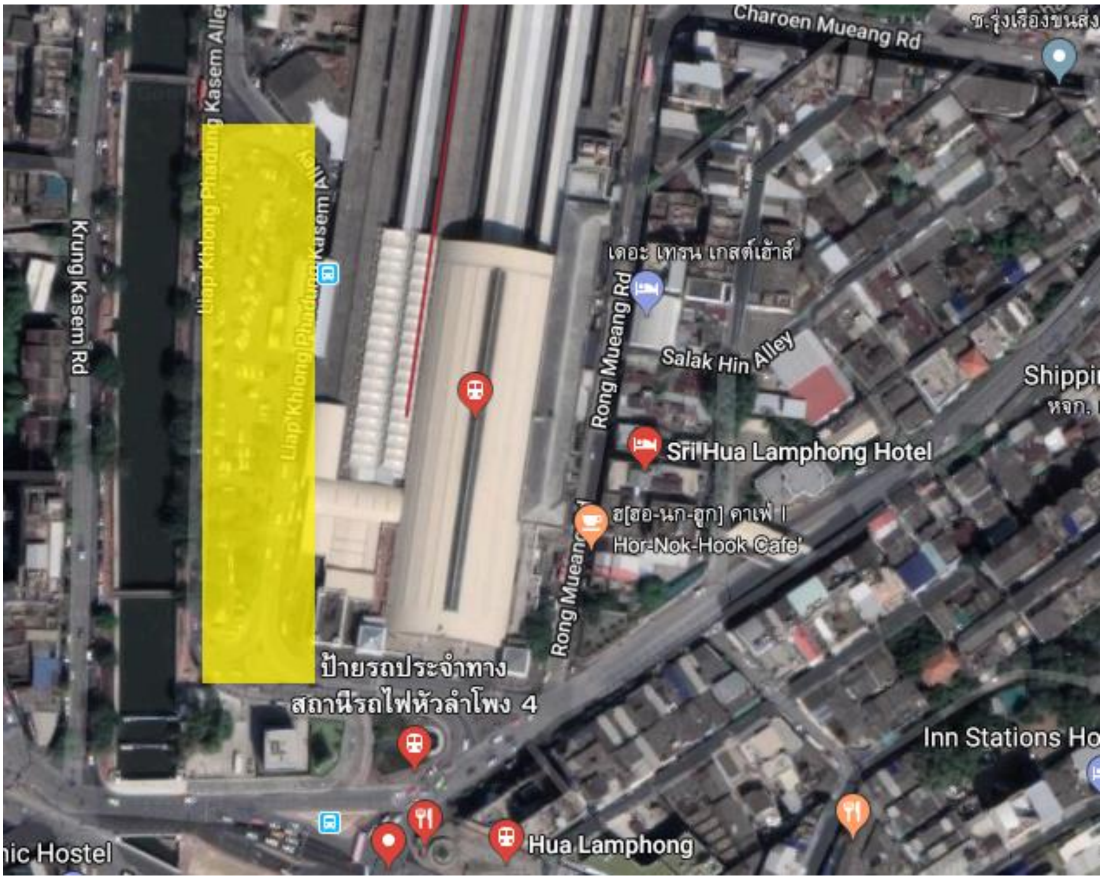

Figure 4.15 Targeting Area for Phathum Wan Future Sub-Transfer Station

In the nearly future, the technology to build a solid waste transfer station will improve and the station size will be smaller and more efficient, The parking area of the Hualamphong train station is still larger than the Ratchavipha sub-station. If this place can be the next transfer station in the future the BMA's total cost of waste management could change and district members of any transfer station must be rearrange on the conditions of VAM technic the results as follow.

Table 4.14 Distance to the Phathum Wan Future Sub-Station

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer Station (k.m.)	Distance to Onnut Transfer Station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)	Distance to Ratchavipa Transfer Sub-Station (k.m.)	Distance to Phathum Wan Future Sub-Station (k.m.)
Pra Nakorn	197.45	30.90	28.30	27.00	17.4	4.9
Dusit	173.86	27.20	26.50	25.90	11.7	5.3
Nong Chok	119.12	34.10	30.30	85.20	37.9	55.2
Bang Rak	170.78	32.60	31.90	25.70	18.9	3
Bang Khen	270.45	10.60	27.70	44.30	7.7	29.8
Bang Kapi	313.18	20.70	14.80	44.70	13.5	20.5
Phathum Wan	287.27	27.50	26.70	27.30	15	1.4
Pomprab Sattru Pai	86.46	29.40	26.80	29.20	14.6	3.5
Pra Ka Nong	149.99	24.80	12.00	41.20	19.6	21
Min Buri	191.42	19.00	19.10	74.00	22.8	37.2
Ladkrabang	255.50	37.90	12.90	70.50	44.9	49.8
Yannawa	183.85	32.20	31.50	28.70	20.2	13.7
Sumpan Thawong	58.51	31.80	31.00	25.90	18.1	2.3
Paya Thai	161.96	22.20	24.60	33.00	7.8	9
Thonburi	164.12	37.70	37.00	16.80	28.3	8.2
Bangkok Yai	85.92	38.00	41.00	20.60	29.8	10.1
Huai Kwang	197.60	18.90	21.60	41.60	8.7	11.6
Klongsan	134.02	35.20	33.20	19.30	21	6.7
Taling Chan	133.33	38.50	37.80	20.80	18.4	14.1
Bangkok Noi	202.02	35.50	33.60	26.20	16.4	9.6
Bang Khun Tien	289.36	53.10	49.10	18.60	40.3	19.4
Pasi Charoen	167.86	42.70	42.00	11.90	32.6	14.3
Nong Kham	173.49	60.90	60.10	8.60	39.4	31.9
Ratburana	116.91	40.80	39.00	25.80	27.8	13.4
Bangplat	152.03	29.80	39.40	27.90	10.9	11.2
Dindang	268.17	24.30	21.70	37.50	12.9	7.7
Buengkum	187.79	17.20	16.60	55.50	17.3	31.6
Sathorn	180.81	34.30	33.60	26.20	21.2	5.2
Bang sue	158.82	24.20	28.70	32.10	7.7	11.2

Table 4.14 (Continued)

District Name	Waste Amount per day (tons) (2015)	Distance to Saimai Transfer Station (k.m.)	Distance to Onnut Transfer Station (k.m.)	Distance to Nongkhame Transfer Station (k.m.)	Distance to Ratchavipa Transfer Sub-Station (k.m.)	Distance to Phathum Wan Future Sub-Station (k.m.)
Jatujak	377.93	22.00	31.30	40.30	1.3	15.6
Bang kolaem	139.17	36.60	35.90	24.80	22.9	11.4
Prawet	270.84	24.20	2.50	52.10	26.6	29.3
Klongtei	339.42	26.20	14.10	34.70	20.6	9.2
Suanluang	237.62	25.30	10.40	50.00	20.1	21.6
Jom Thong	206.39	42.90	40.90	24.00	29.8	16.1
Don Mueang	184.60	16.00	32.90	49.10	14.3	24.8
Ratchathewi	202.58	24.80	23.10	31.40	13.4	4.5
Lat Prao	178.94	12.80	24.40	46.40	9.8	20.2
Wattana	287.42	21.20	17.00	42.20	15.2	11.4
Bangkae	271.63	47.50	52.50	11.70	37.4	26.2
Laksi	156.49	11.70	28.60	43.20	12.9	25.5
Saimai	197.01	0.45	26.30	56.60	24.6	39.1
Kanna Yao	130.28	15.70	13.60	60.10	19.1	40.8
Sapan Sung	118.16	19.20	14.10	56.50	19.3	33.1
Wangthong Lang	213.47	15.20	16.40	46.80	10.2	20.1
Klong Samwa	177.84	12.30	23.10	59.90	23.4	44.2
Bangna	221.44	27.60	22.30	38.60	22.7	18.3
Thawi Wattana	103.31	53.60	52.80	11.00	33.5	35.7
Thungkru	115.12	45.50	34.10	32.10	33.5	26.2
Bangbon	211.20	54.60	56.10	14.70	45.5	40.9
Total amount	9,572.91					

After use VAM technique calculate the result show as table below.

Table 4.15 Cost of BMA's Waste Transfer by VAM Calculation in Case of Phathum Wan Future Sub-Station

District Name	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer Sub-Station (baht/ton)	Cost to Phathum Wan Future Sub-Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	400.46	366.77	349.92	225.50	*63.50	12,538.08
Dusit	352.51	343.44	335.66	151.63	*68.69	11,940.70
Nong Chok	441.94	*392.69	1104.19	491.18	715.39	39,272.67
Bang Rak	**422.50	*413.42	333.07	244.94	38.88	71,192.52
Bang Khen	*137.38	358.99	574.13	99.79	386.21	37,154.42
Bang Kapi	268.27	*191.81	579.31	174.96	265.68	60,071.06
Phathum Wan	356.40	346.03	353.81	194.40	*18.14	5,211.08
Pomprab Sattru Pai	*381.02	347.33	378.43	189.22	45.36	32,942.99
Pra Ka Nong	321.41	*155.52	533.95	254.02	272.16	23,326.44
Min Buri	*246.24	247.54	959.04	295.49	482.11	47,135.26
Ladkrabang	491.18	*167.18	913.68	581.90	645.41	42,714.49
Yannawa	*417.31	408.24	371.95	261.79	177.55	76,722.44
Sumpan Thawong	*412.13	401.76	335.66	234.58	29.81	24,113.73
Paya Thai	*287.71	318.82	427.68	**101.09	116.64	44,503.64
Thonburi	488.59	479.52	*217.73	366.77	106.27	35,733.85
Bangkok Yai	492.48	*531.36	266.98	386.21	130.90	22,938.92
Huai Kwang	*244.94	279.94	539.14	112.75	150.34	48,400.14
Klongsan	456.19	430.27	*250.13	272.16	86.83	33,522.42
Taling Chan	498.96	489.89	*269.57	238.46	182.74	35,941.77
Bangkok Noi	460.08	**435.46	*339.55	212.54	124.42	68,595.89
Bang Khun Tien	688.18	636.34	*241.06	522.29	251.42	69,753.12
Pasi Charoen	553.39	544.32	*154.22	422.50	185.33	25,887.37
Nong Kham	789.26	778.90	*111.46	510.62	413.42	19,337.20
Ratburana	528.77	505.44	334.37	360.29	*173.66	45,348.66
Bangplat	386.21	510.62	361.58	*141.26	145.15	21,475.76
Dindang	314.93	*281.23	486.00	167.18	99.79	75,417.45
Buengkum	*222.91	215.14	719.28	224.21	409.53	41,860.27

Table 4.15 (Continued)

District Name	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost to Ratchavipa Transfer Sub-Station (baht/ton)	Cost to Phathum Wan Future Sub-Station (baht/ton)	Cost of Transfer (bath/day)
Sathorn	444.53	435.46	*339.55	274.75	67.39	78,735.52
Bang sue	313.63	371.95	416.02	*99.79	145.15	15,848.65
Jatujak	285.12	405.65	522.29	*16.85	202.18	6,368.12
Bang kolaem	474.34	*465.26	321.41	296.78	**147.74	60,397.33
Prawet	313.63	*32.40	675.22	344.74	379.73	8,775.22
Klongtei	339.55	*182.74	449.71	266.98	119.23	62,025.61
Suanluang	327.89	*134.78	648.00	260.50	279.94	32,026.42
Jom Thong	555.98	530.06	*311.04	386.21	208.66	64,195.55
Don Mueang	*207.36	426.38	636.34	185.33	321.41	38,278.66
Ratchathewi	321.41	*299.38	406.94	173.66	58.32	60,648.40
Lat Prao	*165.89	316.22	601.34	127.01	261.79	29,684.36
Wattana	274.75	*220.32	546.91	196.99	147.74	63,324.37
Bangkae	615.89	680.40	*151.63	484.70	339.55	41,187.26
Laksi	*151.63	370.66	559.87	167.18	330.48	23,728.58
Saimai	*5.83	340.85	733.54	318.82	506.74	1,148.57
Kanna Yao	203.47	*176.26	778.90	247.54	528.77	22,963.15
Sapan Sung	248.83	*172.74	732.24	250.13	428.98	20,410.96
Wangthong Lang	*196.99	212.54	606.53	132.19	260.50	42,051.46
Klong Samwa	*159.41	299.38	776.30	303.26	572.83	28,349.47
Bangna	357.70	*289.01	500.26	294.19	237.16	63,998.37
Thawi Wattana	694.66	684.29	*142.56	434.16	462.67	14,727.87
Thungkru	589.69	*441.94	416.02	434.16	339.55	50,876.13
Bangbon	707.62	727.06	*190.51	589.68	530.06	40,235.71
Total	2500	3500	3900 (1727.10)	700	700	1,943,038.09

Note: *=main,**=support

From the table above, waste transportation cost of BMA after create the Phathum Wan future transfer sub-station use VAM algorithm calculation is 1,943,038.09 baht per day, that was lower than the total cost from table 4.15 declared as 2,120,401.82 baht per day as 177,363.73 baht per day or 64,737,761.45 baht per year.

In fact, VAM can also be used to calculate BMA's waste management system. For example, in the context of an emergency response plan called the contingency plan in Bangkok, there is a special incident that causes a rapid increase in landfill overnight or a very large amount of landfill in case of a disaster. In this case, the calculation in this case is split into two cases as examples.

4.4.4 Event 4: Case of Songkran Festival on Khao San Road and Silom Road

From the Bangkok Public Relations Office, on 12-15 April 2018, Songkran Festival was held in Bangkok. Phra Nakhon and Silom Road, Bangrak It has been reported that during the three days of Songkran festival, the people attended a large number of events and caused about 30 tons of trash per day at Khaosan Road and around 57 tons of trash per day on Silom Road. In Phra Nakhon district and Bangrak district, the wastewater from Phra Nakhon district was increased by 69,091.70 baht per day and Bang Rak 58,426.81 baht per day. In Bangkok, the total cost of living is 2,290,490.27 baht per day (as shown in the table in Chapter 4, table BMA's municipal waste transfer cost) will increase to 79,589.30 baht per day in Bangkok and Bangrak district. 77,927.37 baht per day, resulting in a total cost of 2,318,143.48 baht per day, an increase of 27,653.21 baht per day. If calculated using the new transport management under the VAM model, the total cost will be reduced to 2,308,725.42, saving can be 9,418.06 baht per day as shown in the table.

Table 4.16 Cost of BMA's Waste Transfer Case of Songkran Festival on Khao San Road and Silom Road

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	227.45	400.46	366.77	*349.92	79,589.30
Dusit	173.86	*352.51	343.44	**335.66	61,108.10
Nong Chok	119.12	441.94	*392.69	1104.19	46,777.23
Bang Rak	227.78	422.50	**413.42	*333.07	77,927.37
Bang Khen	270.45	*137.38	358.99	574.13	37,154.42
Bang Kapi	313.18	268.27	*191.81	579.31	60,071.06
Phathum Wan	287.27	356.40	*346.03	353.81	99,404.04
Pomprab Sattru Pai	86.46	381.02	347.33	*378.43	32,719.06
Pra Ka Nong	149.99	321.41	*155.52	533.95	23,326.44
Min Buri	191.42	246.24	*247.54	959.04	47,384.11
Ladkrabang	255.50	491.18	*167.18	913.68	42,714.49
Yannawa	183.85	417.31	**408.24	*371.95	69,773.43
Sumpan Thawong	58.51	412.13	401.76	*335.66	19,639.47
Paya Thai	161.96	*287.71	*318.82	427.68	46,704.33
Thonburi	164.12	488.59	479.52	*217.73	35,733.85
Bangkok Yai	85.92	492.48	531.36	*266.98	22,938.92
Huai Kwang	197.60	**244.94	*279.94	539.14	55,302.31
Klongsan	134.02	456.19	430.27	*250.13	33,522.42
Taling Chan	133.33	498.96	489.89	*269.57	35,941.77
Bangkok Noi	202.02	460.08	435.46	*339.55	68,595.89
Bang Khun Tien	289.36	688.18	636.34	*241.06	69,753.12
Pasi Charoen	167.86	553.39	544.32	*154.22	25,887.37
Nong Kham	173.49	789.26	778.90	*111.46	19,337.20
Ratburana	116.91	528.77	505.44	*334.37	39,091.20
Bangplat	152.03	386.21	510.62	*361.58	54,971.01
Dindang	268.17	314.93	*281.23	486.00	75,417.45
Buengkum	187.79	**222.91	*215.14	719.28	40,963.93
Sathorn	180.81	444.53	**435.46	*339.55	69,175.16
Bang sue	158.82	*313.63	371.95	416.02	52,401.19
Jatujak	377.93	*285.12	405.65	522.29	107,755.40
Bang kolaem	139.17	474.34	*465.26	321.41	45,285.17
Prawet	270.84	313.63	*32.40	675.22	8,775.22
Klongtei	339.42	339.55	*182.74	449.71	64,028.20
Suanluang	237.62	327.89	*134.78	648.00	32,026.42

Table 4.16 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Jom Thong	206.39	555.98	530.06	*311.04	64,195.55
Don Mueang	184.60	*207.36	426.38	636.34	38,278.66
Ratchathewi	202.58	*321.41	**299.38	406.94	63,967.86
Lat Prao	178.94	*165.89	316.22	601.34	29,684.36
Wattana	287.42	274.75	*220.32	546.91	63,324.37
Bangkae	271.63	615.89	680.40	*151.63	41,187.26
Laksi	156.49	*151.63	370.66	559.87	23,728.58
Saimai	197.01	*5.83	340.85	733.54	1,148.57
Kanna Yao	130.28	*203.47	**176.26	778.90	26,074.88
Sapan Sung	118.16	248.83	*182.74	732.24	21,592.56
Wangthong Lang	213.47	*196.99	*212.54	606.53	45,158.47
Klong Samwa	177.84	*159.41	**299.38	776.30	34,097.10
Bangna	221.44	357.70	*289.01	500.26	63,998.37
Thawi Wattana	103.31	694.66	684.29	*142.56	14,727.87
Thungkru	115.12	589.69	441.94	*416.02	47,892.22
Bangbon	211.20	707.62	727.06	*190.51	40,235.71
	9,659.91				2,318,143.48

Note: *=main,**=support

Table 4.17 BMA's Districts Member Grouped with Transfer Station Case of Songkran Festival on Khao San Road and Silom Road (Current Situation Under Research Constraints)

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer Station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
Dusit	163.22	Nong Chok	119.12	Pra Nakorn	227.45
Bang Khen	270.45	Bang Rak	25.64	Dusit	10.64
Paya Thai	158.53	Bang Kapi	313.18	Bang Rak	202.14
Huai Kwang	0.40	Phathum Wan	287.27	Pomprab Sattru Pai	86.46
Buengkum	72.43	Pra Ka Nong	149.99	Yannawa	145.54
Bang Sue	133.52	Min Buri	191.42	Sumpan Thawong	58.51

Table 4.17 (Continued)

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer Station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
Jatujak	377.93	Ladkrabang	255.50	Thonburi	164.12
Don Mueang	184.60	Yannawa	38.31	Bangkok Yai	85.92
Ratchathewi	150.68	Paya Thai	3.43	Klong San	134.02
Lat Prao	178.94	Huai Kwang	197.20	Taling Chan	133.33
Lak Si	156.49	Dindang	268.17	Bangkok Noi	202.02
Saimai	197.01	Buengkum	115.36	Bang Khun Tien	289.36
Kanna Yao	114.36	Sathorn	81.13	Pasi Cha Roen	167.86
Wang Thong Lang	13.66	Bang Kho Laem	3.86	Nong Kham	173.49
Klong Samwa	136.78	Prawet	270.84	Ratburana	116.91
		Klongtei	331.92	Bangplat	152.03
		Suan Luang	237.62	Sathorn	99.68
		Rachathewi	51.90	Bangsue	25.30
		Wattana	287.42	Bang Kho Laem	135.31
		Kanna Yao	15.92	Klongtei	7.50
		Sapan Sung	118.16	Jom Thong	206.39
		Wang Thong Lang	199.81	Bang Khae	271.63
		Klong Samwa	41.06	Thawi Wattana	103.31
		Bangna	221.44	Thungkru	115.12
				Bangbon	211.20
15	2,309.00	24	3,825.67	25	3,525.24
	[9.00]		[325.67]		(374.76)
				Total	9,659.91

The table shows the members of each regular station transfer.

VAM calcultation

Table 4.18 Cost of BMA's Waste Transfer Case of Songkran Festival on Khao San Road and Silom Road by VAM Calculation

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Pra Nakorn	227.45	400.46	366.77	*349.92	79,589.30
Dusit	173.86	352.51	343.44	*335.66	58,357.85
Nong Chok	119.12	441.94	*392.69	1104.19	46,777.23
Bang Rak	227.78	422.5	413.42	*333.07	75,866.68
Bang Khen	270.45	*137.38	358.99	574.13	37,154.42
Bang Kapi	313.18	268.27	*191.81	579.31	60,071.06
Phathum Wan	287.27	356.4	*346.03	353.81	99,404.04
Pomprab Sattru Pai	86.46	381.02	347.33	*378.43	32,719.06
Pra Ka Nong	149.99	321.41	*155.52	533.95	23,326.44
Min Buri	191.42	*246.24	247.54	959.04	47,135.26
Ladkrabang	255.5	491.18	*167.18	913.68	42,714.49
Yannawa	183.85	417.31	408.24	*371.95	68,383.01
Sumpan Thawong	58.51	412.13	401.76	*335.66	19,639.47
Paya Thai	161.96	*287.71	318.82	427.68	46,597.51
Thonburi	164.12	488.59	479.52	*217.73	35,733.85
Bangkok Yai	85.92	492.48	531.36	*266.98	22,938.92
Huai Kwang	197.6	*244.94	279.94	539.14	48,400.14
Klongsan	134.02	456.19	430.27	*250.13	33,522.42
Taling Chan	133.33	498.96	489.89	*269.57	35,941.77
Bangkok Noi	202.02	460.08	435.46	*339.55	68,595.89
Bang Khun Tien	289.36	688.18	636.34	*241.06	69,753.12
Pasi Charoen	167.86	553.39	544.32	*154.22	25,887.37
Nong Kham	173.49	789.26	778.9	*111.46	19,337.20
Ratburana	116.91	528.77	505.44	*334.37	39,091.20
Bangplat	152.03	386.21	510.62	*361.58	54,971.01
Dindang	268.17	314.93	*281.23	486	75,417.45
Buengkum	187.79	222.91	*215.14	719.28	68,285.12
Sathorn	180.81	444.53	435.46	*339.55	61,394.04

Table 4.18 (Continued)

District Name	Waste Amount per day (tons) (2015)	Cost to Saimai Transfer Station (baht/ton)	Cost to Onnut Transfer Station (baht/ton)	Cost to Nongkhame Transfer Station (baht/ton)	Cost of Transfer (bath/day)
Bang sue	158.82	*313.63	371.95	416.02	49,810.72
Jatujak	377.93	*285.12	405.65	522.29	107,755.40
Bang kolaem	139.17	474.34	465.26	*321.41	44,730.63
Prawet	270.84	313.63	*32.4	675.22	8,775.22
Klongtei	339.42	339.55	*182.74	449.71	62,025.61
Suanluang	237.62	327.89	*134.78	648	32,026.42
Jom Thong	206.39	555.98	530.06	*311.04	64,195.55
Don Mueang	184.6	*207.36	426.38	636.34	38,278.66
Ratchathewi	202.58	321.41	*299.38	406.94	60,648.40
Lat Prao	178.94	*165.89	316.22	601.34	29,684.36
Wattana	287.42	274.75	*220.32	546.91	63,324.37
Bangkae	271.63	615.89	680.4	*151.63	41,187.26
Laksi	156.49	*151.63	370.66	559.87	23,728.58
Saimai	197.01	*5.83	340.85	733.54	1,148.57
Kanna Yao	130.28	203.47	*176.26	778.9	22,963.15
Sapan Sung	118.16	248.83	*182.74	732.24	21,592.56
Wangthong Lang	213.47	**196.99	*212.54	606.53	44,641.00
Klong Samwa	177.84	*159.41	299.38	776.3	28,349.47
Bangna	221.44	357.7	*289.01	500.26	63,998.37
Thawi Wattana	103.31	694.66	684.29	*142.56	14,727.87
Thungkru	115.12	589.69	441.94	*416.02	47,892.22
Bangbon	211.2	707.62	727.06	*190.51	40,235.71
	9,659.91				2,308,725.42

Note: *=main,**=support

Table 4.19 Member of Each Transfer Station by VAM Technique

Saimai Transfer Station	Amount of Waste (ton/day)	Onnut Transfer station	Amount of Waste (ton/day)	Nongkham Transfer Station	Amount of Waste (ton/day)
Bang Khen	270.45	Nong Chok	119.12	Pra Nakorn	227.45
Min Buri	191.42	Bang Kapi	313.18	Dusit	173.86
Paya Thai	161.96	Phathum Wan	287.27	Bang Rak	227.78
Huai Kwang	197.6	Pra Ka Nong	149.99	Pomprab Sattru Pai	86.46
Bang Sue	158.82	Ladkrabang	255.5	Yannawa	183.85
Jatujak	377.93	Dindang	268.17	Sumpan Thawong	58.51
Don Mueang	184.6	Buengkum	132.48	Thonburi	164.12
Lat Prao	178.94	Prawet	270.84	Bangkok Yai	85.92
Lak Si	156.49	Klongtei	339.42	Klong San	134.02
Saimai	197.01	Suan Luang	237.62	Taling Chan	133.33
Wang Thong Lang	46.94	Rachathewi	202.58	Bangkok Noi	202.02
Klong Samwa	177.84	Wattana	287.42	Bang Khun Tien	289.36
		Kanna Yao	130.28	Pasi Cha Roen	167.86
		Sapan Sung	118.16	Nong Kham	173.49
		Wang Thong Lang	166.53	Ratburana	116.91
		Bangna	221.44	Bangplat	152.03
				Buengkum	55.31
				Sathorn	180.81
				Bang Kho Laem	139.17
				Jom Thong	206.39
				Bang Khae	271.63
				Thawi Wattana	103.31
				Thungkru	115.12
				Bangbon	211.2
12	2,300	16	3,500	24	3859.91
	2300		3500		40.09
				Total	9,659.91

The table shows the members of each transfer station as calculated by the VAM technique.

From the above case, it can be seen that if a special event occurs, VAM can be used to spread the burden of each zone. VAM-based calculations can be used to plan events, with projections that can be directly attributed to management planning.

4.4.5 Event 5: Case of Recycle Rate

From 2015 BMA's municipal waste report, amount of waste generated per day was 9,572.91 tons. According to BMA future report, this amount of waste was estimated as 13% recycle rate. Therefore, total amount of waste generate in Bangkok was around 11,003.35 tons per day. From this number, we can make recycle rate projection at 30% and 50% for the clearing picture of BMA's recycle policy in the future

Table 4.20 Recycle Rate Projection

District Name	Waste Amount per day (tons) (2015) as 13% recycle rate	Waste Amount per day (tons) (2015) as 0% recycle rate	Waste Amount per day (tons) (2015) as 30% recycle rate	Waste Amount per day (tons) (2015) as 50% recycle rate
Pra Nakorn	197.45	226.95	158.87	113.48
Dusit	173.86	199.84	139.89	99.92
Nong Chok	119.12	136.92	95.84	68.46
Bang Rak	170.78	196.30	137.41	98.15
Bang Khen	270.45	310.86	217.60	155.43
Bang Kapi	313.18	359.98	251.98	179.99
Phathum Wan	287.27	330.20	231.14	165.10
Pomprab Sattru Pai	86.46	99.38	69.57	49.69
Pra Ka Nong	149.99	172.40	120.68	86.20
Min Buri	191.42	220.02	154.02	110.01
Ladkrabang	255.50	293.68	205.57	146.84
Yannawa	183.85	211.32	147.93	105.66
Sumpan Thawong	58.51	67.25	47.08	33.63
Paya Thai	161.96	186.16	130.31	93.08
Thonburi	164.12	188.64	132.05	94.32
Bangkok Yai	85.92	98.76	69.13	49.38

Table 4.20 (Continued)

District Name	Waste Amount per day (tons) (2015) as 13% recycle rate	Waste Amount per day (tons) (2015) as 0% recycle rate	Waste Amount per day (tons) (2015) as 30% recycle rate	Waste Amount per day (tons) (2015) as 50% recycle rate
Huai Kwang	197.60	227.13	158.99	113.56
Klongsan	134.02	154.05	107.83	77.02
Taling Chan	133.33	153.25	107.28	76.63
Bangkok Noi	202.02	232.21	162.54	116.10
Bang Khun Tien	289.36	332.60	232.82	166.30
Pasi Charoen	167.86	192.94	135.06	96.47
Nong Kham	173.49	199.41	139.59	99.71
Ratburana	116.91	134.38	94.07	67.19
Bangplat	152.03	174.75	122.32	87.37
Dindang	268.17	308.24	215.77	154.12
Buengkum	187.79	215.85	151.10	107.93
Sathorn	180.81	207.83	145.48	103.91
Bang sue	158.82	182.55	127.79	91.28
Jatujak	377.93	434.40	304.08	217.20
Bang kolaem	139.17	159.97	111.98	79.98
Prawet	270.84	311.31	217.92	155.66
Klongtei	339.42	390.14	273.10	195.07
Suanluang	237.62	273.13	191.19	136.56
Jom Thong	206.39	237.23	166.06	118.61
Don Mueang	184.60	212.18	148.53	106.09
Ratchathewi	202.58	232.85	163	116.43
Lat Prao	178.94	205.68	143.97	102.84
Wattana	287.42	330.37	231.26	165.18
Bangkae	271.63	312.22	218.55	156.11
Laksi	156.49	179.87	125.91	89.94
Saimai	197.01	226.45	158.51	113.22
Kanna Yao	130.28	149.75	104.82	74.87
Sapan Sung	118.16	135.82	95.07	67.91
Wangthong Lang	213.47	245.37	171.76	122.68
Klong Samwa	177.84	204.41	143.09	102.21
Bangna	221.44	254.53	178.17	127.26

Table 4.20 (Continued)

District Name	Waste Amount per day (tons) (2015) as 13% recycle rate	Waste Amount per day (tons) (2015) as 0% recycle rate	Waste Amount per day (tons) (2015) as 30% recycle rate	Waste Amount per day (tons) (2015) as 50% recycle rate
Thawi Wattana	103.31	118.75	83.12	59.37
Thungkru	115.12	132.32	92.63	66.16
Bangbon	211.20	242.76	169.93	121.38
Total amount	9,572.91	11,003.34	7,702.34	5,501.67

According to table 4.4, BMA cost to municipal waste management was 2,290,490.27 per day as 13% recycle and if recycle rate growth to 30% and 50%, total cost of system will show in table 4.21

Table 4.21 Total Cost of BMA Dividing by Recycle Rate

District Name	Waste Management cost per day as 13% recycle rate	Waste Management cost per day as 0% recycle rate	Waste Management cost per day as 30% recycle rate	Waste Management cost per day as 50% recycle rate
Pra Nakorn	69,091.70	0	58,267.95	45,443.00
Dusit	58,357.85	0	48,055.98	35,222.64
Nong Chok	46,777.23	0	37,636.85	30,255.11
Bang Rak	56,881.69	0	56,807.71	40,576.94
Bang Khen	37,154.42	42,706.23	29,894.36	21,353.12
Bang Kapi	60,071.06	69,047.19	48,333.03	34,523.60
Phathum Wan	99,404.04	0	79,980.26	58,840.82
Pomprab	32,719.06	0	24,162.19	17,258.71
Sattru Pai				
Pra Ka Nong	23,326.44	26,812.01	18,768.40	13,406.00
Min Buri	47,135.26	0	37,924.92	27,089.23
Ladkrabang	42,714.49	49,097.11	34,367.98	24,548.56
Yannawa	68,383.01	78,601.16	60,389.02	43,135.01

Table 4.21 (Continued)

District Name	Waste Amount per day (tons) (2015) as 13% recycle rate	Waste Amount per day (tons) (2015) as 0% recycle rate	Waste Amount per day (tons) (2015) as 30% recycle rate	Waste Amount per day (tons) (2015) as 50% recycle rate
Sumpan Thawong	19,639.47	22,574.10	15,801.87	13,858.46
Paya Thai	465,397.51	53,560.36	37,492.25	26,780.18
Thonburi	35,733.85	41,073.39	28,751.37	45,229.21
Bangkok Yai	22,938.92	26,366.58	18,456.60	24,318.32
Huai Kwang	48,400.14	55,632.35	38,942.64	27,816.17
Klongsan	33,522.42	38,531.52	26,972.06	33,140.68
Taling Chan	35,941.77	41,312.38	28,918.66	37,538.53
Bangkok Noi	68,595.89	0	70,781.77	50,558.41
Bang Khun Tien	69,753.12	80,176.00	56,123.20	105,822.61
Pasi Charoen	25,887.37	29,755.60	20,828.92	14,877.80
Nong Kham	19,337.20	22,226.66	15,558.66	11,113.33
Ratburana	39,091.20	0	41,319.79	33,960.34
	54,971.01	0	62,460.56	33,744.54
Bangplat				
Dindang	75,417.45	86,686.72	60,680.71	43,343.36
Buengkum	68,285.12	46,438.09	33,680.68	23,219.05
Sathorn	61,394.04	0	49,397.50	46,192.80
Bang sue	49,810.72	0	40,077.59	28,626.85
Jatujak	107,755.40	123,856.78	86,699.75	61,928.39
Bang kolaem	44,730.63	0	35,990.16	37,618.10
Prawet	8,775.22	10,086.46	7,060.52	5,043.23
Klongtei	62,025.61	71,293.81	49,905.66	35,646.90
Suanluang	32,026.42	36,811.98	25,768.39	18,405.99
Jom Thong	64,195.55	50,040.12	51,651.59	62,873.04
Don Mueang	38,278.66	43,998.46	30,798.92	21,999.23
Ratchathewi	60,648.40	69,710.81	52,388.35	37,420.25
Lat Prao	29,684.36	34,119.95	23,883.97	17,059.98
Wattana	63,324.37	72,786.64	50,950.65	36,393.32
Bangkae	41,187.26	47,341.67	33,139.17	23,670.84

Table 4.21 (Continued)

District Name	Waste Amount per day (tons) (2015) as 13% recycle rate	Waste Amount per day (tons) (2015) as 0% recycle rate	Waste Amount per day (tons) (2015) as 30% recycle rate	Waste Amount per day (tons) (2015) as 50% recycle rate
Laksi	23,728.58	27,274.23	19,091.96	13,637.11
Saimai	1,148.57	1,320.19	924.14	660.10
Kanna Yao	22,963.15	26,394.43	18,476.10	13,197.21
Sapan Sung	21,592.56	24,819.03	17,373.32	12,409.52
Wangthong Lang	44,641.00	52,816.80	33,834.50	24,167.50
Klong Samwa	28,349.47	32,585.60	22,809.92	16,292.80
Bangna	63,998.37	73,561.35	51,492.94	36,780.67
Thawi Wattana	14,727.87	16,928.59	11,850.01	84,64.30
Thungkru	47,892.22	0	40,934.82	29,239.16
Bangbon	40,235.71	46,247.94	32,373.56	23,123.97
Total cost	2,279,242.83	1,672,592.28	1,878,231.91	1,527,824.94

According to Table.4.21 above, cost of 13% recycle was 2,279,242.83 baht per day. Capacity of three transfer station was remain 127.09 tons. For none recycle transfer cost was 1,672,592.28 baht per day lower than 13% recycle rate but remain waste in system 1,300 tons per day. About 30% recycle transfer cost was 1,878,231.91 baht per day. Transfer station capacities remain 1,997.64 tons per day. At the 50% recycle level, their transfer cost was 1,527,824.97 baht per day. Transfer station capacities remain 4,198.34 tons per day.

4.4.6 Event 6: Compost Waste

At the Onnut transfer station has a waste composting plant capacity around 1,100 tons per day. This plant specially received biodegradable waste from market directly. After receiving, waste transfer to a short separation line for separate metal and hard plastic waste out. After separation, waste contained to composting process around three month in composting plant until their transform to fertilizer, then crush to smaller matter and fraction some kind of metal, glass and hard plastic. Fertilizers created this way were used in park and Bangkok road side garden.

According to figure 4.11, Bangkok waste composition was combined biodegradable waste around 48% (food waste). Of course, there is only one composting plant at Onnut transfer station occurred. In the future, if the waste compost plant can be built up more, the cost of landfill will be reduced that affect whole system BMA municipal waste management costs as well.

From year 2015 BMA's waste statistics report, average amount of waste per day was 9,572.91 tons, 48% of this waste was biodegradable that approximately 4,595 tons. If we are projecting to reduce waste by 10% to 30% of all daily waste by two others transfer station composting plant creation as Saimai and Nongkham transfer station. The optimization cost of waste management system will be show in table 4.22

Table 4.22 Waste Amount by District Projection by Percentage Reduction

District Name	Waste Amount per day (tons) (2015) as 1,100 tons compost plant	Waste Amount per day (tons) as adding 10% composting rate	Waste Amount per day (tons) as adding 30% composting rate	Waste Amount per day (tons) as adding 50% composting rate
Pra Nakorn	197.45	177.71	138.22	98.73
Dusit	173.86	156.47	121.70	86.93
Nong Chok	119.12	119.12	119.12	119.12
Bang Rak	170.78	155.63	125.32	95.01
Bang Khen	270.45	243.41	189.32	135.23
Bang Kapi	313.18	313.18	313.18	313.18
Phathum Wan	287.27	287.27	287.27	287.27
Pomprab Sattru Pai	86.46	77.81	60.52	43.23
Pra Ka Nong	149.99	149.99	149.99	149.99
Min Buri	191.42	191.42	191.42	191.42
Ladkrabang	255.50	255.50	255.50	255.50
Yannawa	183.85	169.30	140.19	111.08
Sumpan Thawong	58.51	52.66	40.96	29.26
Paya Thai	161.96	146.11	114.40	82.70

Table 4.22 (Continued)

District Name	Waste Amount per day (tons) (2015) as 1,100 tons compost plant	Waste Amount per day (tons) as adding 10% composting rate	Waste Amount per day (tons) as adding 30% composting rate	Waste Amount per day (tons) (2015) as adding 50% composting rate
Thonburi	164.12	147.71	114.88	82.06
Bangkok Yai	85.92	77.33	60.14	42.96
Huai Kwang	197.60	197.56	197.48	197.40
Klongsan	134.02	120.62	93.81	67.01
Taling Chan	133.33	120.00	93.33	66.67
Bangkok Noi	202.02	181.82	141.41	101.01
Bang Khun Tien	289.36	260.42	202.55	144.68
Pasi Charoen	167.86	151.07	117.50	83.93
Nong Kham	173.49	156.14	121.44	86.75
Ratburana	116.91	105.22	81.84	58.46
Bangplat	152.03	136.83	106.42	76.02
Dindang	268.17	268.17	268.17	268.17
Buengkum	187.79	180.55	166.06	151.58
Sathorn	180.81	170.84	150.91	130.97
Bang sue	158.82	142.94	111.17	79.41
Jatujak	377.93	340.14	264.55	188.97
Bang kolaem	139.17	125.64	98.58	71.52
Prawet	270.84	270.84	270.84	270.84
Klongtei	339.42	338.67	337.17	335.67
Suanluang	237.62	237.62	237.62	237.62
Jom Thong	206.39	185.75	144.47	103.20
Don Mueang	184.60	166.14	129.22	92.30
Ratchathewi	202.58	187.51	157.38	127.24
Lat Prao	178.94	161.05	125.26	89.47
Wattana	287.42	287.42	287.42	287.42
Bangkae	271.63	244.47	190.14	135.82
Laksi	156.49	140.84	109.54	78.25
Saimai	197.01	177.31	137.91	98.51
Kanna Yao	130.28	118.84	95.97	73.10
Sapan Sung	118.16	118.16	118.16	118.16

Table 4.22 (Continued)

District Name	Waste Amount per day (tons) (2015) as 1,100 tons compost plant	Waste Amount per day (tons) as adding 10% composting rate	Waste Amount per day (tons) as adding 30% composting rate	Waste Amount per day (tons) (2015) as adding 50% composting rate
Wangthong Lang	213.47	212.10	209.37	206.64
Klong Samwa	177.84	164.16	136.81	109.45
Bangna	221.44	221.44	221.44	221.44
Thawi Wattana	103.31	92.98	72.32	51.66
Thungkru	115.12	103.61	80.58	57.56
Bangbon	211.20	190.08	147.84	105.60
Total amount	9,572.91	8,997.55	7,846.82	6,696.09
		*(-575.36)	*(-1,726.09)	*(-2,876.82)

Note: *=compost amount

From table above, composting rate increased this way was projected by calculate the daily waste average of member of Saimai and Nongkham transfer station reduction in percentage.

Table 4.23 Vam Calculation for Saimai and Nongkham Composting Plant

District Name	Waste Management cost per day as 1,100 tons compost plant	Waste Management cost per day as adding 10% compost rate	Waste Management cost per day as adding 30% compost rate	Waste Management cost per day as adding 50% compost rate
Pra Nakorn	69,091.70	62,182.53	51,883.20	36,209.37
Dusit	58,357.85	53,739.43	42,901.17	30,643.69
Nong Chok	46,777.23	46,777.23	46,777.23	46,777.23
Bang Rak	56,881.69	51,834.02	51,807.73	39,276.97
Bang Khen	37,154.42	33,438.98	26,008.09	18,577.21
Bang Kapi	60,071.06	60,071.06	60,071.06	60,071.06

Table 4.23 (Continued)

District Name	**Waste Management cost per day as 1,100 tons compost plant**	**Waste Management cost per day as adding 10% compost rate**	**Waste Management cost per day as adding 30% compost rate**	**Waste Management cost per day as adding 50% compost rate**
Phathum Wan	99,404.04	99,404.04	99,404.04	99,404.04
Pomprab Sattru Pai	32,719.06	29,256.86	23,060.09	15,015.08
Pra Ka Nong	23,326.44	23,326.44	23,326.44	23,326.44
Min Buri	47,135.26	47,135.26	47,135.26	47,135.26
Ladkrabang	42,714.49	42,714.49	42,714.49	42,714.49
Yannawa	68,383.01	62,969.65	57,230.35	45,347.30
Sumpan Thawong	19,639.47	17,675.52	13,747.63	11,753.49
Paya Thai	465,397.51	42,036.44	32,914.31	23,792.18
Thonburi	35,733.85	32,160.46	25,013.69	17,866.92
Bangkok Yai	22,938.92	20,645.03	16,057.25	11,469.46
Huai Kwang	48,400.14	48,390.35	48,370.75	48,351.16
Klongsan	33,522.42	30,170.18	23,465.70	16,761.21
Taling Chan	35,941.77	32,347.59	25,159.24	17,970.88
Bangkok Noi	68,595.89	61,736.30	49,196.42	43,985.81
Bang Khun Tien	69,753.12	62,777.81	48,827.19	34,876.56
Pasi Charoen	25,887.37	23,298.63	18,121.16	12,943.68
Nong Kham	19,337.20	17,403.48	13,536.04	9,668.60
Ratburana	39,091.20	35,182.08	27,363.84	29,545.50
Bangplat	54,971.01	49,473.91	38,479.71	29,357.75
Dindang	75,417.45	75,417.45	75,417.45	84,454.78
Buengkum	68,285.12	38,974.22	37,016.66	33,787.58
Sathorn	61,394.04	58,009.40	51,240.13	57,032.20
Bang sue	49,810.72	44,829.64	34,867.50	24,905.36
Jatujak	10,7755.40	96,979.86	75,428.78	5,3877.70
Bang kolaem	44,730.63	40,381.63	31,683.63	3,3273.07
Prawet	8,775.22	8,775.22	8,775.22	8,775.22
Klongtei	62,025.61	61,888.56	61,614.45	61,340.34
Suanluang	32,026.42	32,026.42	32,026.42	32,026.42

Table 4.23 (Continued)

District Name	Waste Management cost per day as 1,100 tons compost plant	Waste Management cost per day as adding 10% compost rate	Waste Management cost per day as adding 30% compost rate	Waste Management cost per day as adding 50% compost rate
Jom Thong	64,195.55	57,775.99	44,936.88	48,344.04
Don Mueang	38,278.66	34,450.79	26,795.06	19,139.33
Ratchathewi	60,648.40	56,137.34	47,115.23	38,093.11
Lat Prao	29,684.36	26,715.92	20,779.05	14,842.18
Wattana	63,324.37	63,324.37	63,324.37	63,324.37
Bangkae	41,187.26	37,068.53	28,831.08	20,593.63
Laksi	23,728.58	21,355.72	16,610.01	11,864.29
Saimai	1,148.57	1,033.71	804.00	574.28
Kanna Yao	22,963.15	20,947.44	16,916.02	12,884.61
Sapan Sung	21,592.56	21,592.56	21,592.56	21,592.56
Wangthong Lang	44,641.00	41,782.37	41,244.19	40,706.01
Klong Samwa	28,349.47	26,169.06	21,808.24	17,447.42
Bangna	63,998.37	63,998.37	63,998.37	63,998.37
Thawi Wattana	14,727.87	13,255.09	10,309.51	7,363.94
Thungkru	47,892.22	43103	33,524.56	25,438.07
Bangbon	40,235.71	36,212.14	28,165.00	20,117.86
Total cost	2,279,242.83	2,108,352.59	1,847,396.43	1,630,375.57
		*[702.43]	*[1,853.19]	*[3,003.83]

Note: *=capacity surplus

As can be seen, when there is composting amount increased, their will reduce the cost of whole BMA's municipal waste management system. It was two ways cost savings, firstly saving transferring cost and second saving landfilling cost as well. At 10% adding composting rate, the total transferring cost was 2,108,352.59 baht per day decreased from current situation 170,890.24 baht or 62,374,937.60 baht per year. At 30% composting rate, transferring cost will be 1,847,396.43 decreased from current situation cost 431,846.40 baht per day or 157,623,936 baht per year. Lastly, at the 50%

composting rate the total transfer cost is 1,630,375.57 baht decreased 648,867.26 baht per day or 236,836,549.90 baht per year. In addition, fertilizers from compost process can generate income to BMA.

According to landfilling contract between BMA and private sector company, cost of transfer to landfill and sanitary landfill process was around 680 baht per ton. (Official Information Commission, 2006) As can be seen, If BMA can add 10% compost waste to landfill will decrease 575.36 tons per day that made landfill cost saving as 391,244.80 baht per day or 142,804,352 baht per year. At level of 30% composting, amount of waste to landfill will decrease 1,726.09 tons per day saving landfill cost by 1,173,741.20 baht per day or 428,415,538 baht per year. If composting rate reach to 50%, which made amount of waste decrease 2,876.82 tons per day, saving landfill cost 1,956,237.60 baht per day or 714,026,724 baht per year.

CHAPTER 5

CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

5.1 Conclusion

This study focused on the Bangkok Metropolitan Administration (BMA)'s municipal solid waste management with specific attention to the transportation problem. As described in Chapters 2 and 3, the solid waste management system is problematic and its problems have not been solved or system improved for a long time. The main objective of this study is to develop Vogel's Approximation Method (VAM) to support effective decision making in the area of multi-criteria. Initially, we explore an innovative application to municipal solid waste management. Next, we explore transportation models which can be used to solve the problems. The main goal is to solve BMA's municipal solid waste problem efficiently. The final results of the study are as follows.

From the results in chapter 4 and the demonstration of transportation models, it was found that Vogel's approximation method (VAM) was a practicable model for solving the research problems. Within the limitations of model, the results of the calculations make it more economical than the old system if the new grouping in event 1, which result in savings of up to fifteen million and also provides a more organized approach with regard to the overlapping of cross-border transport.

The BMA has chosen the Jatujak, Dindang and BangSue districts to be in charge. Based on the VAM calculation, Bangplat district will be selected instead of Dindang district to be in charge of the Ratchavipa station. This will result in savings of about four million five hundred thousand baht per year.

As part of future modeling using VAM calculations, the results have emerged dramatically as shown in 4.2.3 (event 3: a new transfer station). The high waste management costs of the Patumwan area are likely to be the highest after Jatujak that created the Ratchavipa sub-station to resolve the high cost of waste transfer. The

BMA will be able to decide if it is necessary to build a new waste transfer sub-station. If this happens, it will reduce the costs. This can be seen from the calculation of VAM, which shows that if it is built in the area of Hua Lamphong train station, it would save nearly sixty-five million baht a year of BMA's overall costs of handling. Of course, this is the result of using VAM to calculate data constraints and variables. But what we need to point out is that VAM has the potential to calculate the management system to address transportation problems especially a large amount of information us needed and it is not complicated.

It is therefore evident that VAM's effectiveness can be used to support empowerment or to support current planning and future planning to improve the efficiency of BMA’s municipal solid waste management.

5.2 Research Discussion

5.2.1 Composting Plant

In the solid waste management system of Bangkok, one part is biodegradable waste collection from the market directly, which is managed by fermentation to produce fertilizer. Fertilizer produced this way is used in parks in Bangkok. This biodegradable waste of about 1,100 tons per day is sent to the composting plant. In the future, BMA will create a new fertilizer plant at Onnut transfer station, the 600 tons capacity per day. This will reduce the amount of waste used to landfill. If there is a project to build a solid waste factory in the form of composting to make fertilizer in the transfer station or create waste separation sites, it will be beneficial to use the waste in the form of fertilizer and reduce the burden of costs for the landfill also. As a proportion of Bangkok's solid waste, nearly 50% of total waste are food waste (48%). Nakayama et al. (2013).

As the results show in 4.2.6, if the compost rate increases 10% that will decrease the amount of waste (575.36 tons per day) and increase the transfer station capacity to receive 702.43 tons of waste per day, which would decrease landfilling costs by nearly four hundred thousand baht per day. If we can increase composting rate to 30% it would decrease amount of waste 1,726.09 tons per day and save landfill costs of 1,173,741.20 baht per day. If the composting rate reaches to 50%, then the amount of waste will decrease by 2,876.82 tons per day, saving landfill costs of 1,956,237.60 baht per day.

A new composting plant is a possible way of developing BMA's municipal solid waste management system that can lower the cost of management due to decreasing landfill usage rate.

5.2.2 Emergency Case of Transfer Station

In some cases, the transfer station cannot handle the solid waste, so the operation must be closed, resulting in the presence of solid residues in the area of the members of the transfer station (National Institute for Environment Studies, 2015). A diagram of very serious flooding is shown below when the Nongkham transfer station was unable to perform its normal duties during the flood.

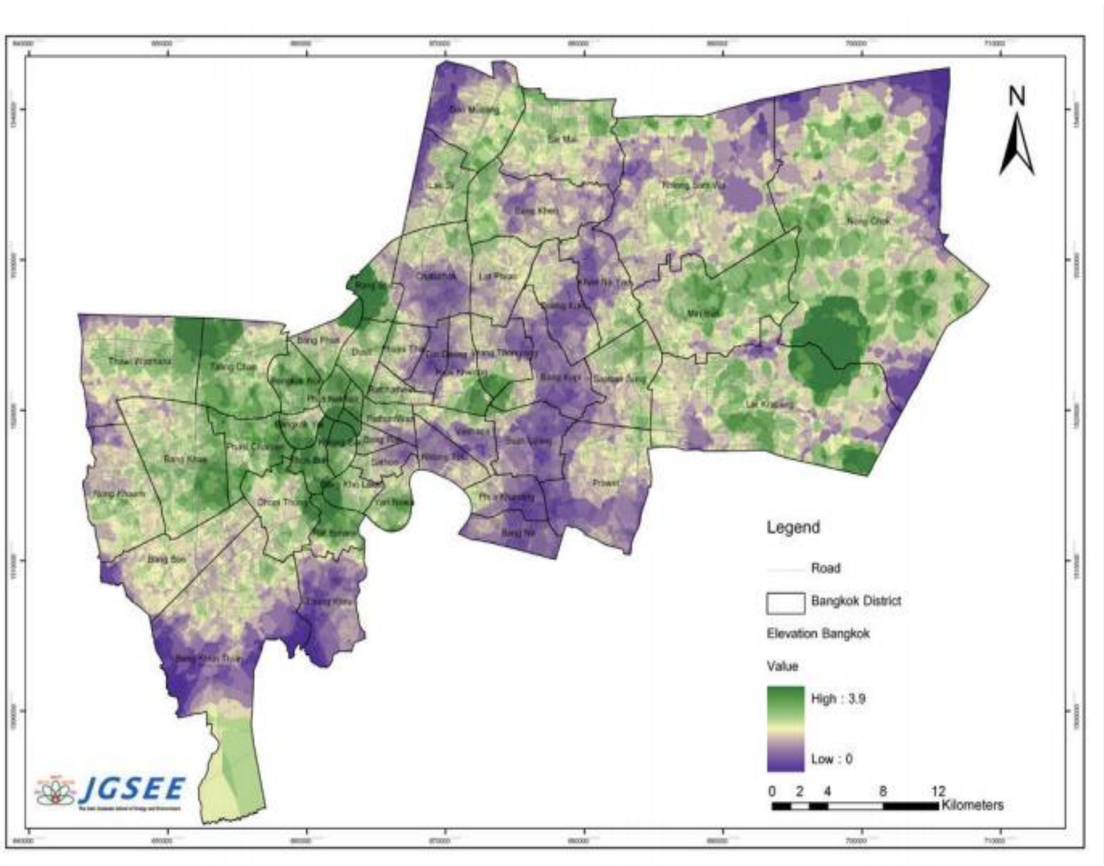

Figure 5.1 Bangkok Flood

Source: National Institute for Environment Studies (2015).

When the Nongkham transfer station was closed, the total amount of solid waste collected in Bangkok was about 9,700 tons per day, which then reduced to 5,800 tons per day. Also, some areas around Nong Khaem landfill were affected because transportation to the landfill was cut off.

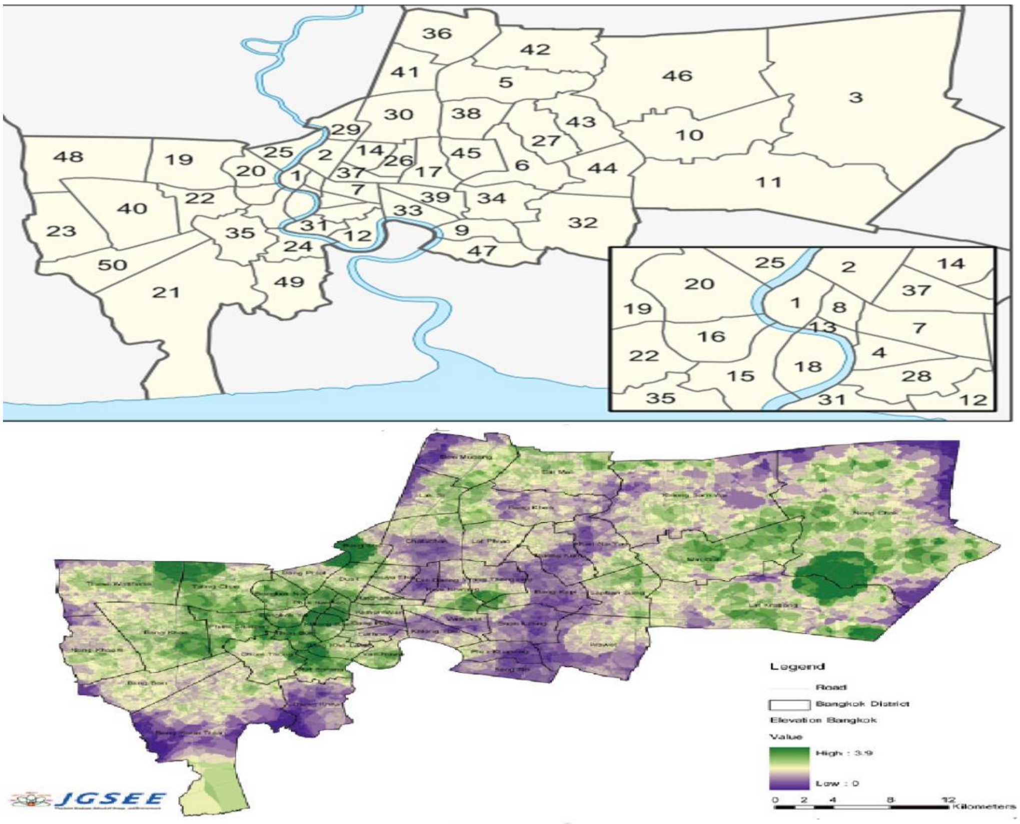

Figure 5.2 Level of Flood in Bangkok Metropolitan Area in 2011 by Districts

It is evident from the above figure that West Bangkok had more serious problems disasters than East Bangkok. The east districts numbers 29, 25, 20, 16, 15, 18, 22, 19, 48, 35, 13, 8, 24, 11 and 3 partially flooded. In this situation, it is not possible to use the normal routes because some roads cannot be crossed due to flooding. If a new emergency transport system was planned, it might alleviate the accumulation of solid waste in each of the areas that are not affected by floods. For instance, in the case of Thonburi south, for example, Ratburana, Thungkru and some parts of Talingchan, planned to send solid waste to another waste disposal center or to another landfill such as Samutpragan landfill instead.

5.2.3 Accumulated Waste after Emergencies

For example, in 5.2.2, if there is flooding, according to the BMA's report, it is likely to have three fold amount of accumulated solid waste. The BMA's average daily waste will exceed the BMA's ability to get into the system. On average, the BMA report shows that the waste is up to 12,000 tones per day after flood. The planned route will make solid waste management system more effective and save more. It is also possible to plan for collection at various stations as scheduled. At each station, there is sufficient space to collect the solids prior to entering the system. Planners can determine the amount that each station will receive in advance. To accelerate the collection of residues in the community to reduce the risk of epidemics after the flood and to maintain the cleanliness of the city. However, emergency planning requires a number of partnerships, including the addition to the contract with the disposal contractor.

5.3 Recommendations

The BMA is trying to create a system that makes municipal solid waste management smooth and effective. They are not trying to solve problems that arise from the system inside. Although the current situation assumes more effective management, there are still problems rooted in the management system itself. So these problems should be carefully investigated and then tackled. The results of the study make it clear that what the problems are and also that the overlap of waste transport routes the various transfer stations should be re-grouped to maximize efficiency.

5.3.1 Recommendations for BMA

5.3.1.1 Overlapping of Waste Transport Routes

Table 4.4 demonstrates the problem of overlapping in BMA’s municipal waste management system as revealed by the researcher. This cause unwanted expenses to occur and it is difficult to control. In each transfer station there are definite members, but overlapping paths still occurred. BMA should be organize the routes carefully and maintain control to see they are used.

5.3.1.2 Re-grouping Members of Transfer Station

Although Bangkok's solid waste management system has now been in operation for a long time, it should be continuously. However, Bangkok will never change or reorganize its membership for each transfer station. The new grouping will support the emergence of new structures in the system. The new grouping should take into account the amount of solid waste in each zone and the combined distances between them. Finally, it should be possible for the solid waste management system to be fully effective and to maximize its value. (see Table 4.7)

5.3.1.3 Ratchavipa Sub-station

Following the results of the VAM calculation technique, it is suggested that Paya Thai, Bangplat, Bangsue and Jatujak districts instead of Dindang, Bangsue and Jatujak should become members of the Ratchavipa sub-station.

5.3.1.4 A New Transfer Station in the Future

The future costs of waste transfer from Pathum Wan district will be over one hundred thousand baht per day. For this the reason, pressure should be put on BMA to build a new transfer station to reduce the costs of transportation. This study found that the area around the Hua Lamphong railway station has the potential to create a transfer station in the future. If it is built in another area, it should be close to the district of Pathum Wan. The most important thing is that Bangkok should start planning as soon as possible for a new transfer station in the future.

5.3.1.5 Increase of Recycling and Composting Rate

According to 4.2.5 Event 5: Case of recycle rate and 4.2.6 Event 6: Compost waste, it is clear that with higher recycling rates and composting the overall amounts of waste can be reduced. The cost of transportation to the station will also be reduced and the landfill cost will be considerably reduced. Therefore, Bangkok should campaign and use regulations as well as seriously plan to create more recycling. In the case of composting, new plants there should be built in the other two transfer stations, which are at Nong Khaem and Bang Khen, for the benefit of converting them into fertilizer and reducing the cost of landfill.

5.3.1.6 A Contingency Plan

A contingency plan should be an important part of Bangkok's solid waste management system. This study found that when events occur, such as natural disasters or unusual events occurrences that increase the amounts of solid waste in a short time, BMA should take rapid decision. At present, there are no plans to deal with the expected or unexpected events. Therefore, a contingency plan should be created and it should be systematic and flexible for dealing with future events.

5.3.2 Recommendations for Further Studies

5.3.2.1 It is recommended that further research should be considered based on the methods and results obtained in this research study regarding the other missions of BMA or other local governments, such as optimization of route transfer costs by using new techniques, management in disaster situations and contingency plan for many kinds of event, and a new management infrastructure.

5.3.2.2 Although, the transportation model is an old technique but this is the first time that it has been applied to study the problems of waste management. Future research may be able to use new emerging techniques based on the information or guidelines of this study.

5.3.2.3 Research topics in the future that are related to the results of this study could include appropriate approaches for establishing environmental learning organizations in the BMA and local organizations for waste management and also methods to improve knowledge about recycle, composting, landfilling and other matters related to disaster management to local government, etc.

5.4 Limitations of the Study

The limitations of this study is the calculation of the formula based on a comparison of transportation based model on Ratchavipa sub-station (BMA, 2015) to make a comparison between the calculation based on the report and the study using the calculations from the VAM technique. The distance data is used as an estimate and does not include labor costs or actual vehicle costs in the calculation, so the costs can not be considered as the real total cost. These may also include other factors such as rental costs, maintenance, or other administrative or management costs of future research.

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APPENDIX

}

VOGEL’s APPROXIMATION METHOD WEB CODE

Code for *https://vamenvinida.com/*

```
<?php
	error_reporting(0);
	$values = $_POST['values'];
	$supply = $_POST['supply'];
	$demand = $_POST['demand'];

	$valus = explode(',',$values);
	//$valus = array_filter($valus);

	$sup = explode(',',$supply);
	$dem = explode(',',$demand);
	$suporg = explode(',',$supply);
	$demorg = explode(',',$demand);
	$m = count($sup);
	$n = count($dem);

	$aa=0;
	$bb=0;
	for($cc=1;$cc<=count($valus);$cc++)
	{
		$c[$aa][$bb] = $valus[$cc-1];
		$bb++;
		if(($cc%$n) == 0)
		{
			$aa++;
			$bb = 0;
		}
	}

	for($i=0;$i<$m;$i++)
	{
	  $rf[$i]=0;
	}

	for($i=0;$i<$n;$i++)
	{
	  $cf[$i]=0;
	}
```

```
$b=$m;
$d=$n;
$sinc = 0;
$einc = 0;
$peva = 0;
echo "<div>";

while($b>0 && $d>0)
{
            for($i=0;$i<$m;$i++)
            {
                $rp[$i]=-1;
            }
            for($i=0;$i<$n;$i++)
            {
                $cp[$i]=-1;
            }
            for($i=0;$i<$m;$i++)
            {
             $k=0;
             if($rf[$i]!=1)
             {
                        for($j=0;$j<$n;$j++)
                        {
                         if($cf[$j]!=1)
                         {
                           $a[$k++]=$c[$i][$j];
                         }
                        }
                        if($k==1)
                        {
                                    $rp[$i]=$a[0];
                        }
                        else
                        {
                                    sort($a,$k);
                                    $rp[$i]=$a[1]-$a[0];
                        }
             }
        }

      for($i=0;$i<$n;$i++)
      {
            $k=0;
            if($cf[$i]!=1)
```

```
        {
                for($j=0;$j<$m;$j++)
                {
                        if($rf[$j]!=1)
                        {
                          $a[$k++]=$c[$j][$i];
                        }
                }
            if($k==1)
                {
                  $cp[$i]=$a[0];
                }
                else
                {
                 sort($a,$k);
                 $cp[$i]=$a[1]-$a[0];
                }
   }
  }
  for($i=0;$i<$m;$i++)
  {
          $a[$i]=$rp[$i];
  }
  for($j=0;$j<$n;$j++)
  {
          $a[$i+$j]=$cp[$j];
  }
  $max=$a[0];
  $p=0;
  for($i=1;$i<($m+$n);$i++)
  {
       if($max<$a[$i])
       {
               $max=$a[$i];
               $p=$i;
       }
  }

$min=1000;
if($p>$m-1)
{
      $p=$p-$m;
   if($cf[$p]!=1)
      {
       for($i=0;$i<$m;$i++)
```

```
        {
                if($rf[$i]!=1)
                {
                 if($min>$c[$i][$p])
                 {
                        $min=$c[$i][$p];
                        $s=$i;
                        $t=$p;
                }
            }
        }
    }
}
else
{
        if($rf[$p]!=1)
        {
         for($i=0;$i<$n;$i++)
         {
                if($cf[$i]!=1)
                {
                 if($min>$c[$p][$i])
                 {
                        $min=$c[$p][$i];
                        $s=$p;
                        $t=$i;
                 }
                }
         }
    }
}

        if($sup[$s]<$dem[$t])
        {
                $sum+=$c[$s][$t]*$sup[$s];
                $str[$sinc] = ($s+1);
                $end[$einc] = ($t+1);
                $muva[$peva] = $sup[$s];
                $cuva[$peva] = $c[$s][$t];
                $dem[$t]-=$sup[$s];
                $rf[$s]=1;
                $b--;
                $sinc++;
                $einc++;
                $peva++;
```

```
        }
        else
        {
                if($sup[$s]>$dem[$t])
                {
                        $sum+=$c[$s][$t]*$dem[$t];
                        $str[$sinc] = ($s+1);
                        $end[$einc] = ($t+1);
                        $muva[$peva] = $dem[$t];
                        $cuva[$peva] = $c[$s][$t];
                        $sup[$s]-=$dem[$t];
                        $cf[$t]=1;
                        $d--;
                        $sinc++;
                        $einc++;
                        $peva++;
                }
                else
                {
                  if($sup[$s]==$dem[$t])
                  {
                        $sum+=$c[$s][$t]*$dem[$t];
                        $str[$sinc] = ($s+1);
                        $end[$einc] = ($t+1);
                        $muva[$peva] = $dem[$t];
                        $cuva[$peva] = $c[$s][$t];
                        $cf[$t]=1;
                        $rf[$s]=1;
                        $b--;
                        $d--;
                        $sinc++;
                        $einc++;
                        $peva++;
                  }
                }
        }
$suin = 0;
$dein = 0;
$yz = 1;
echo "<div align=left> <b> Iteration ".$sinc." </b> </div> <table border=1>";
for($ij=0;$ij<=($m+1);$ij++)
{
        $xy = 1;
        echo " <tr>";
        for($jk=0;$jk<=($n+1);$jk++)
```

```
                {
                        if($ij==0)
                        {
                                if($jk==0)
                                {
                                        echo "<th>   </th>";
                                }
                                else if($jk==($n+1))
                                {
                                        echo "<th> Supply </th>";
                                }
                                else
                                {
                                        echo "<th> D".$xy."</th>";
                                        $xy++;
                                }
                        }
                        else if($jk==0)
                        {
                                 if($ij==($m+1))
                                {
                                        echo "<th> Demand </th>";
                                }
                                else
                                {
                                        echo "<th> S".$yz."</th>";
                                        $yz++;
                                }
                        }
                        else if($jk==($n+1))
                        {
                                echo "<td> ".$suporg[$suin]." </td>";
                                $suin++;
                        }
                        else if($ij==($m+1))
                        {
                                echo "<td> ".$demorg[$dein]." </td>";
                                $dein++;
                        }
                        else
                        {
                                echo "<td> <div style='padding-left: 25px;padding-
bottom:10px;'> <sup>". $c[$ij-1][$jk-1]." </sup> </div>";
                                for($kh=0;$kh<count($muva);$kh++)
                                {
```

```
                    if(($ij==$str[$kh]) && ($jk==$end[$kh]))
                    {
                        echo "<b> ".$muva[$kh]." </b>";
                    }
                }
                echo "</td>";
            }
        }
    echo "</tr>";

    }
    echo "</table><br>";
//  var_dump($suporg);
//  echo "<br>";
//  var_dump($demorg);
//  echo "<br>";
 }
    echo "<table> <tr><td> <b> Total Minimum Cost </b> = ";
    for($hl=0;$hl<count($muva);$hl++)
    {
        if($hl==(count($muva)-1))
        {
            echo $muva[$hl]." &times; ".$cuva[$hl];
        }
        else
        {
            echo $muva[$hl]." &times; ".$cuva[$hl]." + ";
        }
    }
    echo " = <b> ".$sum."</b> </td></tr></table> </div>";

?>
```

BIOGRAPHY

NAME	Mr. Dittawat Kaewkarnjanadit
ACADEMIC BACKGROUND	Bachelor's Degree with major in International Business Administration, University of Thai Chamber of Commerce, Bangkok, Thailand in 2008
	Master's Degree in MBA, Khonkaen University, Khonkaen, Thailand in 2011
PRESENT POSITION	2008-Current Marketing Director, Rungthaveesup Trading Co., Ltd.