STUDY ON OPTIMAL DEDIGN OF SOLID WASTE MANAGEMENT SYSTEM AND ITS FACILITY PLANNING PROCESS IN VIENTIANE CAPITAL, LAOS

By Soulivanh SOUKSAVATH*, Xuepeng QIAN** and Mamoru HARUNA***

1. Introduction

Vientiane Capital is the highest population density area in Laos, it covers a land area about 3920 square kilometers and has population around 698318 (National statistic center, 2005). The population growth rate is 2.99%. The economic growth and urbanization area expansion cause solid waste problem to many areas in Vientiane especially in the urban area which people generate waste approximately 220-250 tons/day (VUDAA, 2005), but municipal solid waste service can collect approximately 120 tons/day, the uncollected waste is burned in an open area and dumped in the selected spots. Vientiane Capital consists of 9 districts. However, the solid waste management service is mainly available in 4 urban districts: Chanthaboury, Sikhottabong, Sisattanak and Xaysettha districts[2]. Municipal solid waste service lacks capacity, planning and fund to handle with these problems. To cope with the problems, it needs to build up the proper plan for improving solid waste management system. Therefore, the objectives of this research focus on:

- Proposing optimal solid waste management to solve the waste problems for environmental safety society.
- Assessing the solid waste facility planning options which aim to maximize the capacity of municipal solid waste collection service and minimize the cost of the facility construction, operation and maintenance cost for finding out the optimum short and long term planning.

2. Current status of Solid waste management in Vientiane

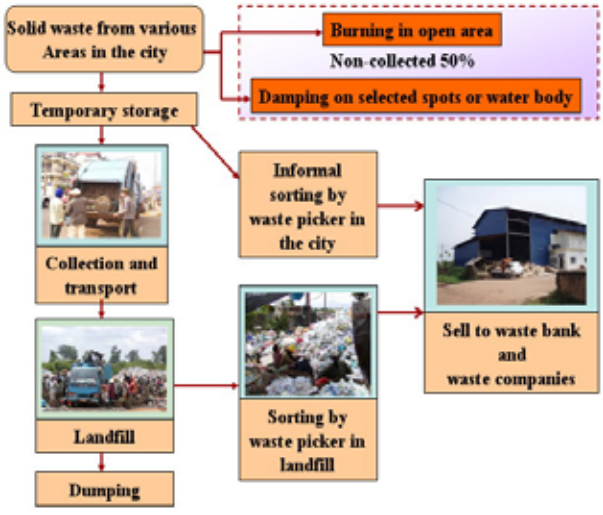

Figure 1: Existing solid waste management

For national level, Science Technology and environment Agency (STEA) responds to develop and formulate the overall strategy, policy and registration concerning solid waste matters. In Vientiane, the municipal waste collection system was developed since 1997 by the supporting fund from JICA, it is the basis system which includes transport and disposal waste as shown in figure 1. This system is managed by Solid Waste Management Planning Unit that implement under the strategy of Vientiane Urban development Administration Authority (VUDAA), Ministry of Communication transport Construction and Post (MCTCP). While Ministry of public health has special responsibility for hospital waste and Ministry of Industry and Handicraft manage the industrial waste. Due to the municipal collection service is not enough, the private companies also involve in waste collection business and waste recycling material buying business such as Lao Garbage Company, Chanthabouly Cleansing Company, KM 7 Waste Buying Company, Lao Chareon Recycling Center and etc. The Participatory Development Training Center (PADETC) is also involved in various activities in urban waste management in Vientiane. PADETC provides integrated waste management programs for youth in schools and communities. This organization is operated on a voluntary basis and receives some financial support from the Embassy of the Netherlands.

3. Proposed Solid Waste Management System Planning

The aims of solid waste management planning are to increase the awareness of environmental problems from garbage, encourage public participation and stimulate public partnerships from various sectors such as municipality, private sectors, NGO, CBO (community base organization) and informal sectors. Furthermore, Law and regulation are also necessary to enforce the plan to implement and prevent an inequality in the society.

There are two major problems from the existing solid waste management in Vientiane (Figure 1). Those are nearly haft of the waste that generates every day in the city is not collected, and the collected waste does not separate from the household level. So majority of the waste only transports directly to the landfill without composting and recycling. To tackle with these problems the municipal solid waste management has to improve its capacity and encourages people to sort and reduce the waste from their households. Waste prevention and separation strategies are proposed in this study. For instance, the municipality should enhance the people to purchase durable-long lasting

Key words: solid waste facility, optimal solid waste management
* Master Course student at Ritsumeikan University
** Post doctor course student at Ritsumeikan University
*** Professor at Ritsumeikan University
Department of Environmental System Engineering, Ritsumeikan University Tel: 077-561-2736

goods, use less packaging, use products that are free of toxic substance and reuse the material. In the proposed solid waste management system planning, the waste will be separated into three main categories: organic waste, none organic waste and hazardous waste in order to make it easy to compost, recycle and burn the waste in a control system. The result from this process, the amount of waste in land fill is reduced and some material in waste stream can reproduce and transform into the other value material such as fertilizer and recycling product. Moreover, it also creates a chance for people to get a job especially poor people who work concerning solid waste. For the industrial and construction waste is excluded from the system boundary.

4. Optimal Solid Waste Facility Planning

To improve the capacity of municipal solid waste service, the facility construction planning is an important stage that we have to consider. The location and the number of facilities should conform to demand of the population and the financial situation[3]. The solid waste facilities which need to be improved and constructed include: recycling facility (material recovery facility), composting facility, transfer station, hazardous waste treating facility and incineration facility. According to the proposed solid waste management, Organic waste is collected and transported to the composting plant. While Non-Organic waste is collected from the source and then transported to materials recovery facility to separate some recyclable material, and the residue from composting plant and recycling facility will be carried through transfer station or directly to landfill. Hazardous waste facility will treat the dangerous substances and dispose them by the proper methodology. Incineration is the alternative that is considered for burning burnable hazardous waste and burnable residue. Furthermore incineration facility can reduce the volume of the waste about 80-95%, which can save the landfill space. Landfill will be used for disposing the ashes from incinerating facilities, residue and materials that cannot be burned. These facilities are planned to construct in 4 zones in service areas and at the landfill site which have population approximately 334966 people. There are three facility planning options that will be assessed in this research:

Option 1: The waste in four planning zones will be transported to four decentralized composting and recycling facilities in each zone. The composting facility and recycling facility have difference capacity from 15 to 25 tons/day and 10 to 20 tons/day respectively. After that the residue from composting and recycling facilities are gather at transfer station and transport to the facilities in the landfill site. For Hazardous waste will be collected and transported directly to the hazardous waste treating facility in the landfill site.

Option 2: The central composting and recycling facility is planned to be constructed inside the city. This mean the waste from planning zones will be sorted in one central facility which has composting capacity 85 tons/day and recycling capacity 65 tons/day. Then the residue from this process will transport to the facility in the landfill site. For the hazardous waste is the same as option1.

Option 3: The central integrated solid waste facility is planned to build in the landfill site outside the city, the facility capacity is the same as option 2, but the larger transfer station will be constructed at the haft way from the waste sources to the landfill site. For the hazardous waste is the same as options 1 and 2. Further detail are shown in the below figure.

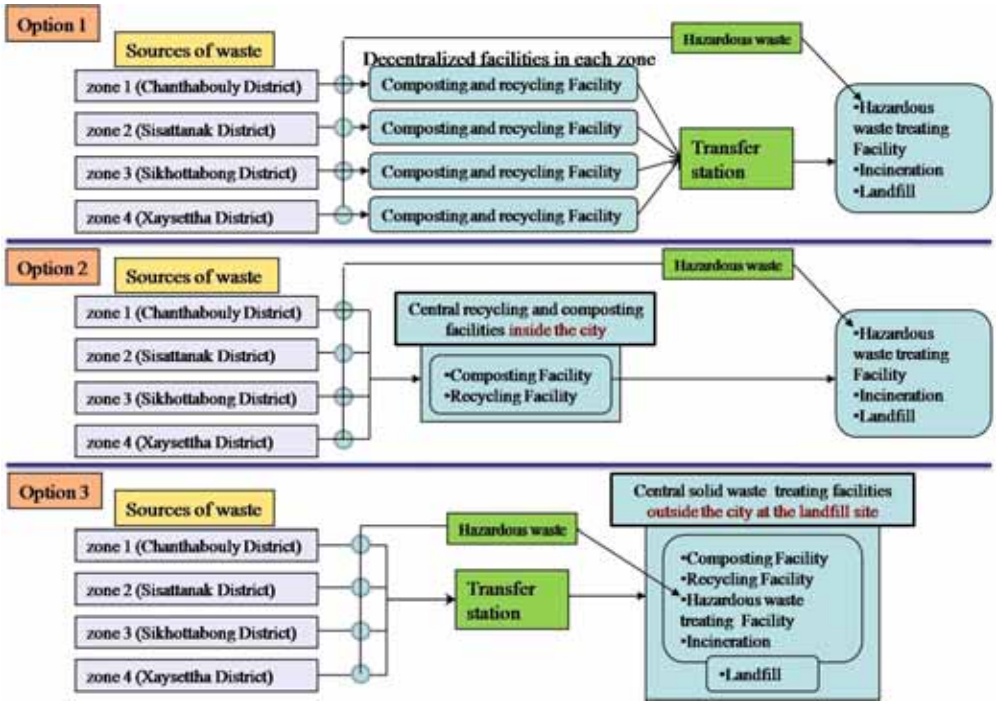

Figure 2: The flow diagram of facility planning option

5. Mathematical Model

This part deals with the application of a group of mathematical models to the systematic analysis of the solid waste management system[1]. In the facility investment problem, there are two cost components: expenditure cost and revenue which would be considered when forming the mathematical investment evaluation model. Linear optimization model is useful to find the optimal amount of fund to allocate for constructing and running the facility. The expenditure cost model aim to minimize three component costs: the total transportation cost, capital cost and running and maintenance cost. This mathematical model can be formed as follow:

Objective function of expenditure cost (C)

$$\text{Min} \sum_{j\in I\cup J}\sum_{i\in S} f_{ij}E_{ij} + \sum_{k\in L}\sum_{j\in L} f_{jk}E_{jk} + \sum_{j\in I\cup J} p_j \sum_{i} f_{ij} + \sum_{j\in I\cup L} F_j y_j$$

Subject to:

$$\sum_{j\in I\cup J} f_{ij} = G_i, \qquad i \in S,$$

$$\sum_{i\in S} f_{ij} - a_j \sum_{k\in L} f_{jk} = 0, \qquad j \in I,$$

$$\sum_{i\in S\cup I} f_{ik} \le C_k Y_k = 0, \qquad k \in L,$$

The revenue mathematical model of solid waste management aims to maximize the income from selling composting product (bio fertilizer), recycling material and waste service fee. This mathematical model is formed as below:

Objective function of the revenue (R)

$$\text{Max} \sum_{j\cup k} RC_j + \sum_{j\cup k} RR_j + \sum_{i\in S} RH_i$$

Where:
f_{ij} = flow from i to j
y_j=1 if the facility j is already in existence
S= set of sources
G_i=quantity of waste generated at source i
I= set of intermediate facilities yet to be built and the intermediate facilities already in existence
L= set of facility at landfill site that may be built and landfill facilities that already exist
F= locations of potential facilities
E_{ij}= expenditure transportation cost at facility j
p_j= running and maintenance cost at facility j
C_k= capacity of facility k
$RC_{j\,U\,k}$ = annual revenue of composting facility j and k
$RR_{jU\,k}$ = annual revenue of recycling facility j and k
RH_i = annual revenue of household waste service fee including collection fee, incineration and hazardous treating

The objective function of solid waste facility investment refund model is to minimize the difference of expenditure cost and the revenue of the facility. For the long term planning, it concerns how to determine the numbers of facility, capacity of the facility, the location and the administration during the time period 'T'. This type of problems can be handled as a control mathematics problem of the discrete variables in the dispersal time[4].

Besides, the objectives can be reached as follows: establish a recycling system by construction and proper management of facilities which will allows us to have more controlled and accurate data; by recycling, treatment and burning of the waste, the amount of waste to landfill will be reduced. It was considered the reduction of cost for facilities as the first objective function considering the economical conditions as a priority to waste management and the reduction of waste to landfill can be considered as the second objective function or status function.

This is all the formularization regarding the objective function, project variable and the state space. Including each boundary condition, to bring a conclusion of this formularization of model, it will be as following:

Objective Function

Min V(T)= C (Expenditure Costs) – R (Revenue)

Status function

$$P(t) = p(t) + P(t-1)$$

$$V(t) = v(t) + V(t-1)$$

Plan variable

$$\$(t) = \{s_1(t), s_2(t), \cdots s_j(t), \cdots s_n(t)\}$$

Where: V(T) refund of the facility investment in time period t, P(t): amount of waste to landfill until period t, $\$(t)$ vector showing 1= facility exists 0= does not exists

These mathematic models will be applied to evaluate the three proposed planning options as mention above to find out the optimal plan of solid waste facility and compare these options in order to observe the change of investment value through the location and the capacity of the identified facilities.

6. Result

After the data were input to the mathematical models, the outputs of the computing program were shown in Figure 3, 4 and 5. The brief detail of output from the mathematical model is described as follow:

Three planning options were estimated through the cost unit and the above mathematical models. The comparison output of these proposed options and the existing system was shown in figure 3 which shows

that the planning option1 has a lowest running and maintenance cost about $1107810 per year due the decentralized composting and recycling help to reduce the waste and the numbers of trips which generate from sources to landfill. Moreover, the capital cost also lower than option 2 and 3 because they have small amount of loading waste and can operate by the low cost technique which is difference from the big facility which has to use higher standard technique to cope with a big amount of waste. It can be assumed that option 1 is the optimal option in the criteria that the land area of the facility is subsidized by the government and excluded from the estimation. While the existing system has low revenue due to the income mainly collect from the service fee.

The financial investment planning of solid waste facility for the next 20 years is computerized. In order to show the profitability of a system, it can be analyzed from the refund graph (refund = total expenditure cost – revenue). The analysis results of the optimal option 1 are shown in figure 4 which includes graphs for: Capital cost expense, Conveyance (transport) expense, running and maintenance cost and Refund. The investment for this plan is high at the beginning around 5.2 million dollars. However, municipality expects to be recovered in refund since the 12th years. For option 2 and 3 have to spend more than 17 years to refund the cost that was spent to establish the solid waste facility.

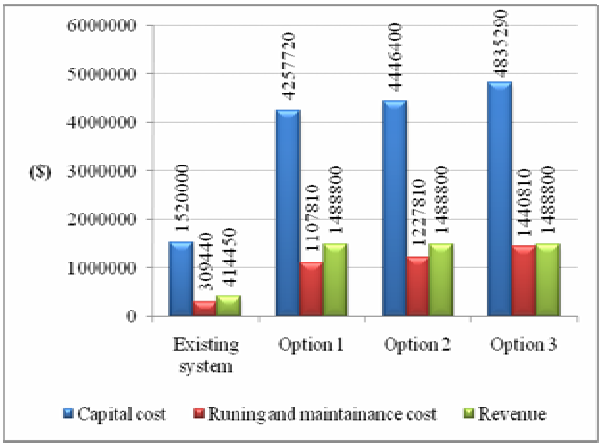

Figure 3: planning option comparisons

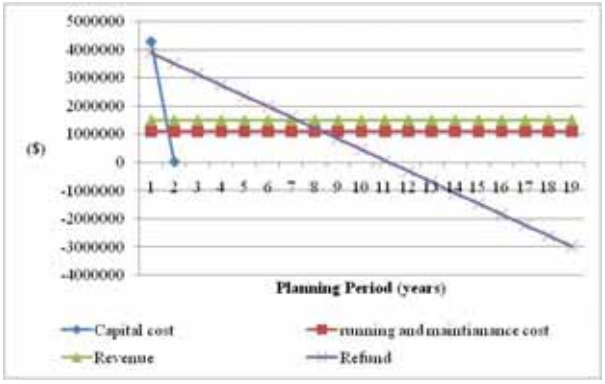

Figure 4: investment expense for 20 years of planning option 1

From the proposed planning, the facility can reduce the big amount of waste to landfill in each year as show in the below figure.

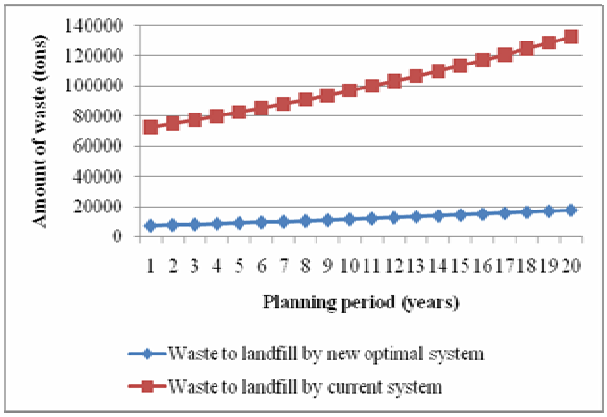

Figure 5: Waste reduction prediction at landfill

6. Conclusions

In Vientiane, solid waste problems seem to increase significantly in each year because of the expansion of urban area, so it is important to find the optimal way to manage the waste. This research tries to propose the optimal solid waste management such as improving the solid waste collection system, using the waste prevention and separation strategies, and educating the waste awareness in order to attract the participation of people. Furthermore, How to find the optimal fund to allocate to improve the capacity of municipal solid waste service is the key study of this research. To assess the facility planning, the mathematical solid waste facility investment model was formed and applied to evaluate three facility planning options aiming to find out the optimal option because Lao government has a limited fund. From the mathematical analysis show that the municipalities have to invest about 5.2 million dollar at the beginning for constructing the facilities and they can recover in refund in the 12th years.

References

1) Gottinger, H.W. Economic Model and Applications of Solid Waste Management. Amsterdam: Gordon and Breach Science Publishers S.A, 1991.
2) Sengtianthr,V. Solid Waste Management in Urban Areas of Vientiane Capital City using GIS. Paper presented at 30th WEDC International, 2004 Conference, Vientiane, 2004.
3) Forbes, M.D., *et al*: Integrated solid waste management: a life cycle inventory, 2003
4) Tachibana Junzo. A study on development of model on derirable waste disposal system in regions, Doctor thesis, Ritsumeikan University (Japan), 2003