# STUDY ON FACILITY PLANNING FOR ENCOURAGING THE INTEGRATED SOLID WASTE MANAGEMENT IN VIENTIANE CAPITAL, LAOS*

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## 1. Introduction

The capital city of Laos is Vientiane which is located in the middle west of Laos, it has population about 698318 (National statistic center, 2005) and covers the land area around 3920 square kilometers. Vientiane is the same as other developing city, the economic growth and urbanization area expansion stimulate many environment problems especially solid waste problems. In the urban district area, Vientiane people generate waste approximately 220-250 tons/day[2)], but municipal solid waste service can collect only haft of the total amount of waste, the uncollected waste is inappropriate management such as burning in an open area and dumping in the selected spots. In addition, the uncollected waste problem causes the environment problem that has the bad effect to people's health and also scenery in the city. The solid waste collection service seems to not enough to the demand of people and municipality lacks of planning and fund to handle with these problems. To cope with these problems, the integrated waste management is proposed, and it is required to build up the proper plan especially the solid waste facility planning. Two objective of this paper was set to deal with those problems. First objective is to introduce solid waste management strategies to solve the waste problems for environmental safety society, and the second objective is to assess the solid waste facility planning 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 solid waste management.

## 2. Current Solid Waste Management and Its Problems in Vientiane Capital

The waste collection and transportation system in Vientiane have improved since 1997 by the supporting fund from Japanese government through JICA. JICA implemented the project to improving the collection system for one year; it provides the equipment for collection and transport such as waste collection trucks, waste containers. Furthermore, it also supported to build the truck maintenance shop and the office of Urban Cleansing Service Center (UCSC), this center provides the waste collection registration service for the households. The UCSC belongs to Vientiane Urban development Administration Authority (VUDAA) which implements under the policy of Vientiane governor office and Ministry of public work and transportation. For national level, Science Technology and environment Agency (STEA) responds to develop the overall policy and regulation concerning solid waste management. While Ministry of public health has special responsibility for hospital waste and Ministry of Industry and Handicraft manages the industrial waste. However, there some problems occur in this current solid waste management in Vientiane as following:

- Majority of people do not separate the waste in their own households and they still rely on the old methodologies to get rid of the waste such as burning and dumping waste by inappropriate way. People lack of awareness on the proper disposal of solid waste.
- The waste management service is insufficient to demand of people, and the vehicles for waste collection are insufficient for reaching all communities.
- Majority of waste was dumped in the landfill without recycling and composting program.
- Vientiane people confront health risks and environmental impact caused by inappropriate management of garbage. An inappropriate waste dumping also pollutes natural rivers and created high health risks for human and livestock.
- Some households are reluctant to pay for the waste collection fee
- Government has a limited fund to allocate to construct the solid waste management facility.

## 3. Proposed Waste Management Strategies

Waste Reduction Strategy (Source Reduction): One of the important problems of solid waste problem in Vientiane is the large amount of waste was generated in every day. To avoid the generation of waste, this research proposes waste reduction strategy which is the reduction or elimination of the quantity or toxicity of residual waste before it is generated. Source reduction may be achieved through changes within the production process including process modifications, feedstock substitutions, improvements in feedstock purity, shipping and packing modifications, housekeeping and management practices. For instance, waste reduction would include purchasing durable, long-lasting goods and seeking products and packaging that are as free of toxic substances as possible.

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* Key Words: solid waste facility, optimal solid waste management

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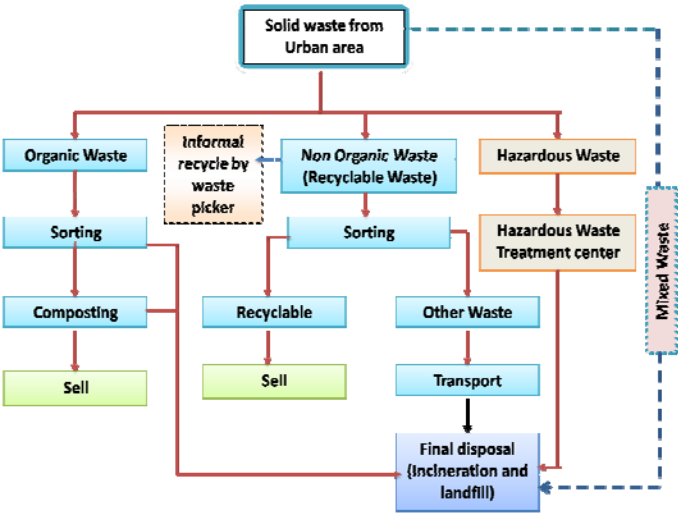


Figure 1. proposed integrated solid waste management

Waste Separation Strategy: This strategy is a key stage of this research because it is the first stage before the waste flows to the planning system. Because Vientiane Municipality does not have the facilities to support the separation strategy, the people only dump many kinds of waste in the same garbage bins or containers. In this study, the facilities will be planned for the waste separation strategy. Waste separation means people in each household sort the waste into difference categories, this will help the waste collection process to achieve its aiming easily and the waste can be taken to the material recovering process such as recycling and composting. However, the efficiency of waste separation strategy is up to the participation of people.

In the proposed solid waste management strategies, 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 (for detail see figure 1).

## 4. Identify Solid Waste Facility Planning Patterns

To implement the integrated solid waste management strategy, this research has proposed to establish some necessary solid waste management facilities including recycling facility (material recovery facility), composting facility, transfer station, hazardous waste treating facility and incineration facility. For improving 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. According to the proposed solid waste management, there are three categories of waste which will be managed in different kind of facility. Organic waste is collected and transported to the composting plant. While Non-Organic waste is collected from household 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 some burnable hazardous waste and burnable residue. Landfill will be used for disposing the ashes from incinerating facilities, residue and materials that cannot be burned. These facilities are planned for 4 urban districts (Chanthabouly, sisattanak, Sikhothabong and Xaysetha district) which have population approximately 334966 people. There are three optional facility planning pattern that will be assessed in this research:

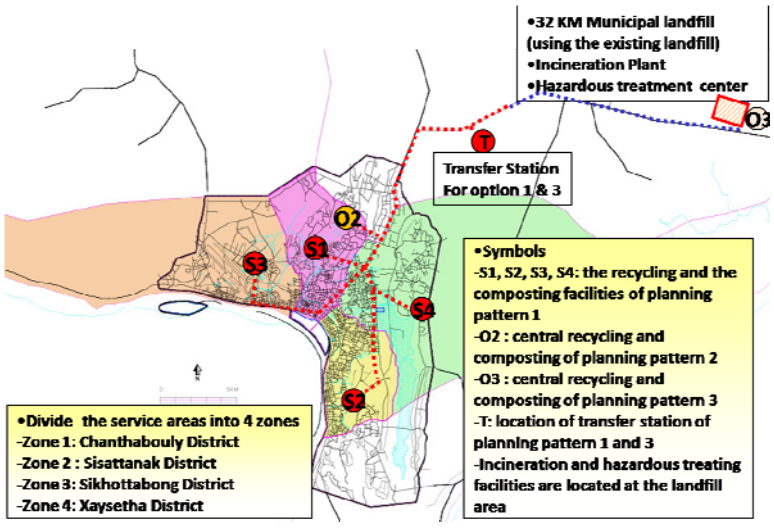


Figure 2. Location of the facilities for each planning pattern

Planning pattern 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 capacities from 15 to 25 tons/day and 10 to 20 tons/day respectively. After that the residue from composting and recycling facilities gathers at transfer station and transports 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.

Planning pattern 2: The central composting and recycling facility is planned to be constructed inside the city. This means 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 option 1.

Planning pattern 3: The central integrated solid waste facility is planned to build at the landfill site outside the city, the facility capacity is the same as pattern 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.

## 5. Mathematical Model Formulation for Solid Waste Management Planning

For analysis the proposed facility planning patterns above, it is important to form the suitable mathematical model for the particular planning. In addition, this paper uses the application of a group of mathematical models to the systematic analysis of the solid waste management system. In the facility investment problem, there are two main 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. For the main objective function of solid waste system model is to minimize the differences between cost and revenue during the planning period (t), we can form the mathematic model as following:

$$\text{Min} \sum \text{Cost(t)} - \text{Revenue(t)}$$

To modify the model in more detail, we have to identify the detail of the expenditure cost and the revenue. For the expenditure cost model, there are three subsystem costs which are the running and maintenance cost of waste collection and transportation, capital cost and running and maintenance cost of processing facility[3)]. The reason for separating the running and maintenance cost of waste collection and transportation from the maintenance cost of processing facility is waste transportation has a specific cost because its activities mainly rely on the routes of vehicle and the petroleum price. For The revenue, its mathematical model of solid waste management aims to maximize the income from selling composting product (bio fertilizer), recycling material and waste service fee. Finally, the detail of mathematical model for the solid waste facility planning can be formed as below:

**Objective function**

$$\text{Min} \sum_{(i\in Z;\, j\in Su)} \sum_{v\in V} E_{ijv}\delta_{ijv} + \sum_{(j\in Su;\, k\in F)} \sum_{v\in V_1} E_{jkv}\delta_{jkv} + \sum_{H\in Su\cup F} \text{Pr}_H \sum_i \delta_{ij} + \sum_{H\in Su\cup F} \text{Ec}_H Y_H$$
$$- \sum_m \sum_{i\in Z} \sum_{j\in Su} (\lambda_m \times \text{PC}_m \times G^R{}_{ij}) \times \text{Ur}_m - \sum_{i\in Z} \sum_{j\in Su} G^C_{ij}(1-\text{Vr}_j)\text{Uc} - \sum_{i\in Z} \text{Bh}_i$$

Where:

$\delta_{ijv}$ = Binary variable that takes on the value 1 when vehicle v visits trip j immediately after trip i, 0 otherwise; $E_{ijv}$ = Expenditure cost of associating trip i to trip j using vehicle m; $E_{jkv}$ = Expenditure cost of associating trip j to trip k using vehicle $v_1$; $\text{Pr}_H$ = Processing and maintenance cost at facility H; $\text{Ec}_H$ = Capital cost of establishing facility H; $Y_H$ = Has the value 1 for the new facilities in the plan, and 0 if the facility already existed; H=All new planning solid waste treating facilities; $\lambda_m$=percent of material m in waste, sold as recyclable raw material; $\text{PC}_m$ = percent of material m in solid waste; $G_{ij}$= amount of waste flow through the facilities; $\text{Ur}_m$: unit selling price of material m, $; $\text{Vr}_j$= volume reduction ratio at compost facility Su; Uc= revenues from composting facilities; $\text{Bh}_i(t)$ = revenue of household waste service fee; Z = set of collection sources; Su = Set of recycling and composting facility.

The first term of the equation is the running and operation cost of waste collection and transportation from source i to intermediate facility (recycling and composting) j by vehicle type v, the second term is the waste collection from the intermediate facility j to the final disposal center k by vehicle type v. While the third term is the running and maintenance cost of processing facilities, the fourth term is the capital cost of the facilities. In addition, the fifth term is revenue from recycling facility, the sixth term is revenue from composting facility and the seventh term is the revenue from the collection fee.

**Some constraint of the objective function**

- Mass balance constraint: All solid waste generated at source i should be shipped to intermediate facilities and landfill. Except the recyclable waste which households sell to the waste picker or recycling company

$$\sum_{j=1}^{Su} G^R_{ij} + \sum_{j=1}^{Su} G^C_{ij} + \sum_{k=1}^{F} G^{In}_{ik} + \sum_{k=1}^{F} G^{Ht}_{ik} + \sum_{k=1}^{F} G^L_{ik} = \sum_{i=Z}^{Z} G_i + G_{Hr}$$ ($G_{ij}$;$G_{ik}$ are amount of waste to each facilities)

- Capacity of the facility constraint: the capacity of the facility must be higher than the amount of collecting waste

$$\sum_{i\in Z\ j\in Su} G_{ij} \le C_{max,j}$$ ($C_{max,j}$: maximum capacity of facilities j )

- Material limitation constraints: material from the facilities must be greater than the reject waste to the landfill[1)]

$$\sum_{j\in Su\ k\in F} G_{jk} \le \text{PC}_j \sum_{i\in Z} G_i$$ ( Gjk= reject waste to landfill, PCj = percentage of waste can be recycled and composted)

## 6. Result Discussion

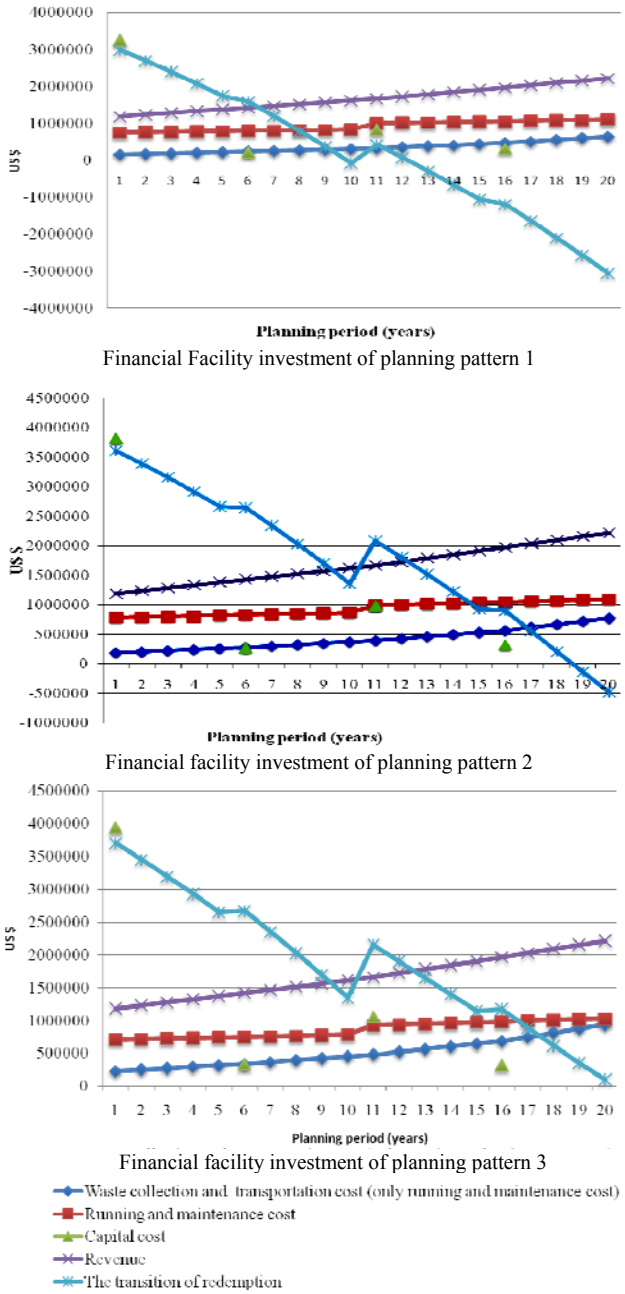


Figure 3. Financial facility investments of three planning patterns

In the new solid waste management system, the old facilities also use in this system in order to save the investment budget such as the existing collection facilities. In the long term facility investment from 2010 to 2029 (figure 3), we can observe that the money refund of the first planning pattern is faster than other patterns. This pattern spends the time to payback the debt only 12 years. Actually, the facilities seem to have no debt from the tenth year, but at that time, they have to invest more money for expansion of the size and capacity of the facilities, so in the 11th year they still have debt until the 12th year. After that the operation of the facilities can generate the profit to the owner. Furthermore, the municipality invests lower capital cost if comparing to other patterns about US $5040460. For the running and maintenance cost of waste collection and transportation, this pattern is also lower than other patterns. In the first year period, this pattern spends only US $154190, while the pattern 2 and 3 spend US $187069 and US $228866 respectively. From the analysis shows that the cost of the waste transportation cost is the key factor to affect the result of money refund or debt payment (redemption). For the second pattern, it spends the time to payback the debt of the facilities until the 17th year and the third pattern is about 22nd year. The capital cost of recycling and composting facility in pattern 3 is lowest because the municipality does not have to pay for the land rent. However, they have to spend more to buy the waste transport facilities. For the second pattern, the center recycling and composting facility has the larger size and higher capacity, so it cannot use the low cost technique to operate this facility like pattern 1 and it cause the expensive capital cost. Finally, it can be concluded that the first pattern is the optimum pattern which has the suitable amount of money to investment to improve the solid waste facilities in the urban districts in Vientiane Capital under some constraints.

## 7. Conclusions

This research tries to propose some strategies to solve the solid waste problem in Vientiane such as waste reduction strategy and waste separation strategy and the integrated solid waste management. Furthermore, facility planning is the key study of this research which aims to improving the capacity solid waste collection and recover recyclable material before disposal. The planning facilities include recycling plant, composting plant, transfer station, incineration facility and hazardous facility. To assess the planning, the mathematical solid waste facility investment model was formed base on linear optimization programming and applied to evaluate three planning patterns. From the analysis show that the first pattern is the optimal planning under some restrict condition. The municipalities have to invest about 5.04 million dollar to construct the facilities in the planning period and they can payback all the debt in the 12th years. Furthermore, it can reduce the big amount of waste to landfill if comparing to the existing system.

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