FINANCIAL FEASIBILITY OF COMPOSTING MARKET WASTE IN VIENTIANE, LAO PDR

by

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Abstract

"Financial Feasibility of Composting Market Waste in Vientiane, Lao PDR"

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The feasibility of market waste composting in Vientiane was studied from a financial perspective. Four alternatives were evaluated in this study as follows.

Alternative A1 is a centralized composting facility outside the city. Alternative A2 is a centralized facility in the city. Alternatives A3 and A4 are decentralized composting plants at four different sites. A3 involves off-site facilities near markets, while A4 involves on-site facilities.

As a result of the study, it was noted that A4 is the best alternative which generates the highest net benefit. On the other hand, A2 is the second best alternative; at the same time, it has a negative balance. A1 and A3 are not found to be profitable, either. A1 requires the highest waste transportation cost. A3 shows the highest operation and maintenance costs. A sensitivity analysis was also conducted. A4 is always better than the other alternatives regardless of the changes in uncertain parameters.

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1. Introduction

This study examines the financial feasibility of composting market waste in the city of Vientiane, in the Lao People's Democratic Republic (PDR). This chapter introduces Laos, and explains the background of the project, including the current waste collection system used in the city. It also outlines the financial analysis used in the project. Finally, it describes the purpose of the study and structure of the report.

1.1 Introduction to Laos and Background of the Project

The Lao PDR, commonly referred to as Laos, is the only landlocked country in South East Asia, neighbouring Thailand, Cambodia, Vietnam, China and Myanmar (See figure 1.1). It is one of the poorest countries in the world with a Gross Domestic Product (GDP) of US $2.0 billion and a GDP per capita of US $320 in 2003 (World Bank, 2004). This country was also ranked 135 out of 177 countries in 2002 in terms of the Human Development Index, which was evaluated by the United Nations Development Programme (UNDP, 2004).

Figure 1.1 Map of Lao PDR (CIA, 2004)

Figure 1.2 Map of Vientiane (Urban Research Institute, 2004)

Vientiane has been the capital of Laos since 1560. This city, with the total area of 3,920 km² and population of 692,900, is located on the Mekong River (See figure 1.2), and is the centre of culture, business and administration in Laos. Every day, 220 tonnes of waste are generated in Vientiane (Asian Development Bank, 2004). The city may encounter serious waste management problems as it continues to grow and the economy expands.

This project was carried out a part of the Waste-Econ program, which is a six-year collaborative programme between the University of Toronto and partners in Laos, Vietnam, and Cambodia. The Waste-Econ program in Laos aims to promote local waste management strategies (Waste-Econ, 2004), and it is operated by the National Council of Science (NCS) in Laos. More than 50 percent of municipal waste in developing countries can be composted (Hoornweg *et al*., 1999). Therefore, composting can be an important element in sustainable waste management. In the summer of 2003, two projects were carried out. One was the study of quantification and composition audit of market waste (Chopra, 2004), and the other was the analysis of separation options for composting market waste (Wong, 2004). The purpose of each project was to determine whether the market waste was suitable for composting, and to seek how to establish composting for market waste in the city. From June to July 2004, this project was conducted in Vientiane in order to analyze the costs and benefits of composting waste from four major markets in the city. This financial analysis is essential to the Vientiane municipality for the successful development of a composting programme.

Figure 1.3 Waste collection in Vientiane

There are currently two waste management organizations in Vientiane; the Lao Garbage Service and the Vientiane Cleansing Organization. They collect residential and commercial waste in different districts of the city (See figure 1.3), and 40 percent of the city's daily waste is collected (UNDP, 2003). Of this collected municipal waste, the Vientiane Cleansing Organization, with 20 garbage trucks, is in charge of 80 percent, and the Lao Garbage Service, with 6, collects the rest.

There are over 10 small and large markets across the city, and most of the major markets' waste is collected and transported to the dumpsite according to contracts between the markets and garbage companies. This market waste contains a high proportion of organic waste (Chopra, 2004), and it easily decomposes. Therefore, the market waste is a good organic source of composting.

1.2 Benefits of Composting

Composting is a biological decomposition process in a controlled aerobic or anaerobic environment (CIAS, 2002). Besides oxygen, there are four other key factors to control during the process: carbon to nitrogen (C/N) ratio, moisture, pH, and temperature. Through the composting process, organic raw waste is converted into humic substances, which are compost.

Composting can provide several economic benefits (Otten, L., 2001;Hoorweg, D. *et al*, 1999), although it sometimes also has negative environmental impacts such as odour and leachate, and financial problems. The benefits that composting bring into communities are as follow.

- extension of landfill life-time
- cost savings from reduced waste transportation to landfill
- cost savings from avoided waste disposal at landfill
- creation of new jobs
- revenue from the sale of compost

In addition, there can be environmental benefits, such as reduced methane generation at landfill sites.

1.3 Overview of Financial Analysis

It is necessary for local decision makers to be informed as to whether a proposed project, including waste composting, makes economic sense or not before implementing it. This financial analysis will provide the likely costs and benefits of composting. The most demanding part in this analysis is estimating the monetary values of each aspect of a composting facility. It should involve all possible components of expenditure and incomes derived from current market prices as accurately as possible. There are three basic types of costs and benefits, and each type involves different several components as follows. These components are discussed in depth in chapter 2.

- Capital costs
    - land

  - facility construction
  - utility installation
  - equipment
  - vehicles
- Operation and maintenance (O&M) costs
  - salaries (labour)
  - utilities
  - tools/supplies
  - truck operation and maintenance
  - shipping
  - disposal of rejects
  - others
- Benefits
  - revenue
  - cost savings

The costs of building and operating a composting plant vary by size, location, sophistication of technology and so on. Four alternatives, including centralized and decentralized facilities, are compared through the measure of net benefit. In addition, supplementary sensitivity analyses are needed to address uncertainties in the estimation of parameters.

1.4 Objectives and Structure of the Study

The main purpose of this project is to analyze the financial feasibility of a proposed compost facility for market waste in Vientiane. Overall, the study provides quantitative assessment of costs and benefits of different composting facilities. This study involves the following;

- to develop a financial analysis framework
- to identify and estimate the components of costs and benefits of a composting facility
- to investigate the possible alternatives of a composting plant
- to analyze and evaluate the financial feasibility of each alternative
- to conduct sensitivity analysis in order to reflect uncertainties on the analysis

This report is structured in five sections.

Section two presents the principles of financial analysis, an analysis framework, how data were collected and how cost-benefit components were estimated. The data sources and estimation methods are explained in three subsections according to the types of costs and benefits, capital costs, O&M costs and benefits.

Section three provides the total costs and benefits of each alternative. The alternatives are compared through using a measure of net benefit. Both on-site and off-site composting facilities were considered as alternatives. For an accurate estimate of cost and benefit, project specific criteria such as composting location, site condition, facility size and level of technology are defined.

In section four, sensitivity analyses were carried out with different uncertain parameters such as interest rate, lifetime, and compost price. The analysis provides the effect of the uncertainties on the decision criterion.

Section five is a summary and conclusion, and suggests recommendations for a market waste composting program in Vientiane.

2. Methodology

2.1 Framework of Financial Analysis

An engineering project should be assessed for economic feasibility along with technical specifications because a project is of little value if it cannot benefit either a project proponent or a community. For this reason, it is necessary for engineers to identify all of the costs and all of the benefits of a project. There are two techniques commonly adopted in engineering economic analysis: financial analysis and cost-benefit analysis (CBA). In financial analysis, all related costs and benefits are estimated and evaluated on the basis of market prices. On the other hand, CBA quantifies all possible costs and benefits in terms of social gains and losses. In this study, financial analysis was conducted.

This financial analysis requires a general framework which identifies and assesses the costs and benefits of the project. The general procedure of the analysis comprises the following five steps.

1) identification of alternatives
2) identification of all possible costs and benefits
3) estimation of costs and benefits
4) comparison of costs and benefits of each alternative
5) selection of a project

2.1.1 Identification of alternatives

In this project, four alternative composting facilities were identified for the market waste composting. Alternative 1 is a centralized composting facility outside Vientiane, and Alternative 2 is a centralized composting facility in the downtown area of the city. Alternatives 3 and 4 are decentralized facilities sited near and within the four different markets, respectively. The alternatives are described in more detail in section 3.1.

2.1.2 Identification of components of costs and benefits

There are three basic types of costs and benefits: capital cost, operation and maintenance costs and benefits. Capital costs are initial investment costs in order to establish a project. They are generally one of the largest items in project expenditure. Each item under capital costs can have a different lifetime (Curry, J. and Weiss, J., 1993). For instance, land preparation will be permanent, and does not need to be repeated, while machinery has a limited lifetime. In this case, machinery requires replacement, which incurs replacement costs. Operating and maintenance funds are necessary to operate and maintain an item until the end of the life of the project. Operating cost is measured on an annual basis, but maintenance costs can be assessed on an as-needed basis. Machinery either has a regular annual maintenance schedule or is repaired when necessary (Szonyi, A.J. *et al.*, 2000). Benefits are from the output of the project, or from cost savings. There can be revenue from the sale of a product and indirect benefits either outside or inside of organizations. For example, organic waste disposal at landfill would be avoided by composting, bringing reduced disposal cost to communities.

Based on the three types above, in this study, components of costs and benefits related to composting activity were identified and estimated, based on the data from on-site interviews, local market surveys and literature.

Capital costs involve land preparation, facility construction, utility installation, and equipment and vehicle acquisition. Operation and maintenance costs include labor, utilities, tools and supplies, fuel, vehicle maintenance, shipping cost, land leases and so on. Last, as benefits, compost sale, avoided landfill costs and reduced transportation costs were considered. Table 2.1 gives more details of each component. Only financial costs and benefits were considered. Other costs, such as environmental impacts due to potential odour and leachate problems during the composting process, were not addressed. The monetary value of the items in the table are quantified and aggregated to estimate the total costs and benefits.

Table 2.1 Components of costs and benefits for composting

Capital costs	Land	
	Facility construction	site preparation pad and roof of process area water pond fence office building, machinery room storage access road drainage system water supply
	Utility installation	electricity, water, telephone
	Equipment	shredder, water pump office furniture computer/printer air conditioner telephone
	Vehicle	truck
Operation and maintenance costs	Salaries	supervisor office worker operators, truck driver
	Utilities	electricity, water, telephone
	Tools and supplies	shovels, rakes, hoses, bags, sieves, hand carts, uniforms, gloves, boots etc.
	Truck O&M	fuel, repair and other maintenance
	Land rent	rental payment
	Shipping	compost organic or inorganic waste rejected
	Disposal of rejects	organic or inorganic waste rejected
	Amendments	manure, rice bran
Benefits	Revenue	sale of compost
	Cost savings	landfill disposal waste transportation to landfills

2.1.3 Estimation and discounting of costs and benefits

This step is a demanding task to gain a clear picture of the true costs and benefits of a project. Desirability of a project is usually expressed in terms of money. Not only are costs and benefits expressed in monetary value, but also they should be expressed in terms of the time value of money, that is dollars at a particular time. Generally, resources used or generated in earlier years are weighed higher than those in later years. This weight, called discounting factor, over a certain period can be mathematically expressed as follows (Watkins, T., 2004; Szonyi, A.J. *et al.*, 2000; Nas, T.F., 1996; Curry, J. and Weiss, J., 1993).

$$\text{Discountng factor} = \frac{1}{(1+r)^n}$$

where, r = compounded discount or interest rate (in decimals)

n = number of years in the future

There are assumptions in this equation that the discount rate is constant year to year, and the same rate is applied to both costs and benefits. Given the discounting factor, the following equation shows the relationship between the present value (P) and the future value (F) of an amount of money.

$$P = F \times \frac{1}{(1+r)^n} = F\ (P \mid F\ r, n)$$

where, r = compounded discount or interest rate (in decimals)

n = number of years in the future

In the case of a uniform series of cash flows, an annuity factor is applied instead (Szonyi, A.J. *et al.*, 2000; Riggs, J.L,.*et al.*, 1982)

$$\text{Annuity factor} = \frac{r(1+r)^n}{(1+r)^n - 1}$$

where, r = compounded discount or interest rate (in decimals)

n = number of years in the future

Therefore, an annualized capital cost (A) is calculated by the following equation.

$A = P(A|P\ r, n)$

where, P = capital cost

r = compounded interest rate (in decimals)

n = amortization period (years)

2.1.4 Comparison and selection of projects

There are several decision criteria used with discounted values of costs and benefits in order to evaluate the viability of a single project or the better among several alternatives (Fuguitt, D. and Wilcox, S.J., 1999). In this report, two decision criteria are used. First is the difference between benefits and costs, which is a net benefit generated by a composting facility. A project is worthwhile to do if benefits exceed costs.

$$\text{Net benefits} = (\text{total benefits}) - (\text{total costs}) \qquad > 0 \quad \text{acceptable}$$

$$= \begin{Bmatrix} \text{revenue} + \\ \text{cost savings} \end{Bmatrix} - \begin{Bmatrix} \text{capital costs} + \\ \text{operation and maintenance costs} \end{Bmatrix}$$

Second is cost per kilogram, which divides total annual costs by the amount of annual compost product projected.

The alternatives defined in section 2.1.1 are compared and ranked based on the decision criteria, and plausible choices between alternatives can be made. The results of financial analysis are influenced by uncertain factors such as interest rate. Supplementary analyses are performed to test how sensitive the outcomes are to changes in the uncertain factors.

2.2 Data Sources and Estimation Methods of Costs and Benefits

This section explains how information was collected and how cost-benefit components for this project were estimated, including the estimation of the facility capacity and of the site area. In addition, the key assumptions to estimate each component of a composting facility are described. Other assumptions used to quantify the monetary values are:

- total 5 tonnes of composting capacity per day
- labour intensive windrow system for composting technology
- on-site organic waste separation at markets for feedstock of composting
- same benefits of composting in all alternatives.

Three currencies, the Laotian kip, the Thai baht, and the US dollar, are commonly used in Laos. All the costs and benefits in this study were converted to US dollars. Exchange rates applied in this study are as follows.

- 1 US dollar = 10,000 kips
- 1 US dollar = 40 bahts

2.2.1 Estimation of a facility capacity

To estimate the amount of organic waste feedstock for a composting plant, each market manager and the waste collection companies were contacted. The capacity of a composting plant was calculated based on the amount of organic waste from the four markets in question: the Thong Khankham Market, the Khuadin Market, the That Luang Market and the Sikhay Market. It was estimated that 5 tonnes of organic waste is available everyday by using the following equation.

$$\text{Required capacity (tonne/day)} = \text{Percentage of organic} \times \text{Total market waste (tonne/day)}$$

Where,

$$\text{Percentage of organic} = \frac{\text{total organic waste (tonne/day)}}{\text{total market waste (tonne/day)}}$$

$$= \frac{\text{average organic waste per food vendor (kg/day)} \times \text{No. of the vendors}}{\text{total market waste (tonne/day)} \times 1{,}000}$$

Organic waste is mostly generated from the food section in the markets. Therefore, the daily organic waste amount per food vendor was used. The average waste amount, dependent on the type of a vendor, was quantified by Chopra (2004). The number of food vendors was given by the market managers, according to the type of the vendor. The total waste generated from the four markets is 14 to 16 tonnes per day according to the landfill manager. As a result, the amount of organic waste from the four markets ranged between 42% and 50% of total waste, which is between 5.9 tonne/day and 8 tonne/day. However, it is difficult to separate all the organic waste from mixed waste at the markets. Therefore, a 5 tonne facility size was used in this study, which is a smaller amount than the estimated minimum amount of organic waste generated from the markets.

2.2.2 Estimation of site areas

Estimation of the land area required for the facility site was necessary to quantify a land cost and a facility construction cost. The required areas for a composting site depend on the amount of waste feedstock that the facilities can compost. The composting site in this study is largely made up of compost processing areas: a sorting pad, a composting pad, a curing area, a screening and bagging pad, a compost storage area, a waste storage area, and a reject storage area. In addition, a composting facility needs an office, machinery room, drainage system, water pond, fence, and access road. Usually, half of processing area is a composting area, and one quarter of the composting area is a curing area (US EPA, 1994). Figure 2.1 describes a layout of the windrow composting plant.

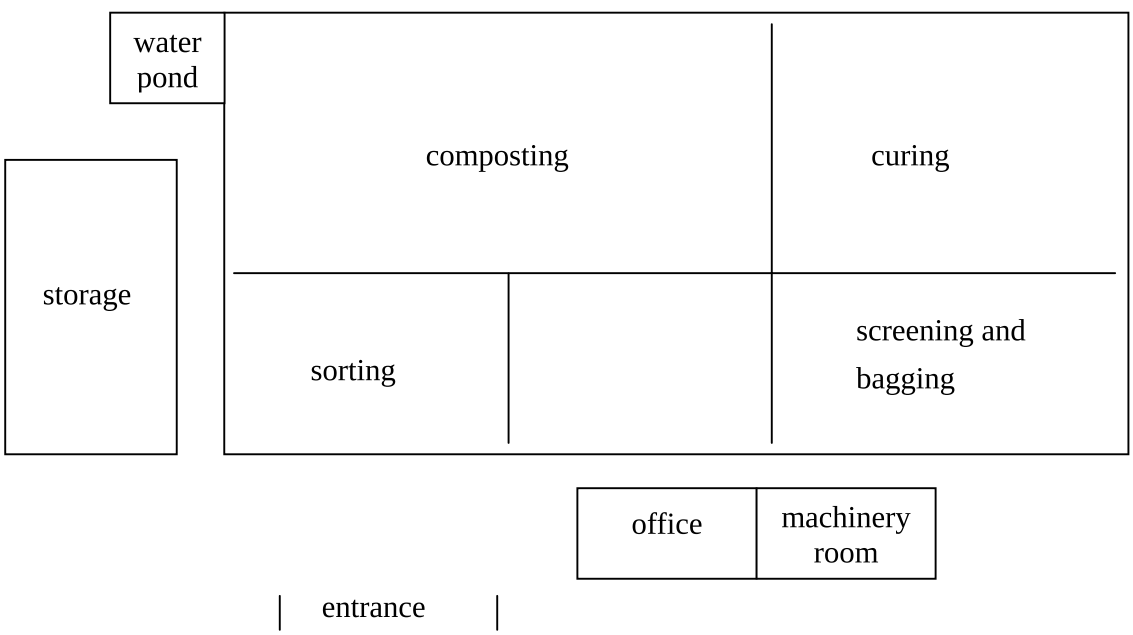

Figure 2.1 Layout of a composting plant using a windrow system

The total area, excluding the area of the access road, was estimated to be 1,000 m^2 for a 5 tonne daily capacity based on a case study of a similar 3 tonne facility in Dhaka, Bangladesh (SANDEC and Waste

Concern, 2001). The processing areas described in table 2.2 were estimated by multiplying each area of the 3 tonne facility in Dhaka by 1.7 for the 5 tonne facility in this study. The length of drainage system and fence was determined based on the perimeter of the composting site area.

Table 2.2 Design specifications of a composting facility with a 5 tonne daily capacity

Component		Lifetime (year)	Length (m)	Area (m^2)
Processing areas:	Sorting pad	20		60
	Composting pad	20		351
	Curing pad			157
	Screening &bagging	20		60
	Storage of Compost	20		71
	Storage of Rejects			104
	Storage of Waste			60
	Water pond	20		17
Office and machinery room		20		30
Drainage system		20	126	
Fence		20	126	
Access road		20~25	50	(300)
Extra space				90
Total				**1,000**

For each of the four smaller decentralized facilities, it was assumed that the capacity and site area would be one fourth of the centralized facility. Therefore, each decentralized facility requires 250 m^2.

2.2.3 Capital costs

To estimate annual capital costs, the total of the various capital cost elements was multiplied by an annuity factor, assuming a 20 year amortization period and a 12% interest rate. Twenty years is the lifetime of the facility building. Interest rates for loans were investigated from four banks. The banks have three different rates depending on whether the loan is in kips, bahts or US dollars. Laotian kip accounts have the highest interest rate, which ranges from 18% to 28%. Thai baht and US dollar accounts fluctuate from 6% to 16%. The interest rates depend on the loan period and type of a loanee’s business. In this study, a typical interest rate of the US dollar accounts was used because most projects in Laos are funded by foreign investment. Below is an explanation of the estimation of each component of the capital costs. Detailed data for each alternative are provided in dollars and kips in appendices 1-1a through 1-2d.

2.2.3.1 Land

To implement a composting facility, the project has to first acquire a site. The site can be either donated to project owners by the Laotian government, or purchased or rented by project owners. Land prices in Laos depend on the proximity to the center of the city and main roads. A local real-estate agent provided the price of rural area land near the Vientiane landfill as $\$6/m^2$, and downtown areas up to $\$120/m^2$. According to statistics provided by the Department of Domestic and Foreign Investment (DDFI, 2003), prices for industrial land vary between $\$2/m^2$ and $\$50/m^2$. The facility outside the city would not have land cost because the site would be donated by the municipality. For other alternatives, rental of land was assumed due to the high land cost. This matter is discussed in section 2.2.4.4 since rent would be an operating cost.

2.2.3.2 Facility construction

Three local construction companies were contacted to estimate a facility construction cost including site clearance. The facility design specifications were given to the companies. Two of the three estimates were used in this study. The estimate from the other company was discarded due to uncertainty about the reliability of the data. Based on the average of two estimates, a unit cost, cost per square meter, was calculated for the pad and roof of the composting process areas. The unit costs were used to recalculate the construction costs with different sizes of processing areas. Also, all other unit costs of construction, such as a drainage system and a water pond were calculated. The facility construction cost was estimated by multiplying a unit cost of each building facility by the number of units, and totaling those costs as shown in appendices1-1a through 1-2d.

Both labour and construction material costs are included in the construction costs. The transportation cost of construction material to the site was not considered in this analysis because there is no charge within 25 km from the city.

For the centralized composting plants, the pads were designed with a thickness of 15 cm of concrete to support the weight of a truck which comes on and off of the pad frequently, and the roof height is 4 m. On the other hand, the decentralized facilities have a pad thickness of 10 cm, and a roof height of 2.5 m. Sorting, composting, screening and bagging floors are roofed to mitigate the amount of leachate, and to alleviate severe weather conditions. All processing areas are paved, except a curing area, to reduce the risk of soil and groundwater contamination. The facility has one office building, and a storage room to keep equipment, tools and supplies. The water pond is built to collect leachate and rainfall through a drainage system. The collected water will be recycled on site.

2.2.3.3 Utility installation

Local utility suppliers were contacted to investigate the installation fees of electricity, water, and telephone. There is one supplier for each service in Vientiane, and for each service, all the same fee is applied over the Vientiane prefecture. The installation fees for electricity, water, and telephone are $90, $70, and $60, respectively.

2.2.3.4 Equipment

Prices of equipment were surveyed at local markets. Several different hardware shops near the China market, the Thong Khankham market and the That Luang market were visited to average the prices of the shredder and submergible water pump. The prices of ready-made industrial size grinders (which are normally used for ice or coffee beans) were also used. In addition, the market prices of office furniture and office machines were investigated, and averaged. There is a replacement cost for the equipment because their lifetime was assumed to be 10 years, which is shorter than the 20-year facility amortization period.

2.2.3.5 Truck

A truck is mainly used for organic waste collection from the markets. In addition, the same truck can be used for shipping of rejects to the landfill and shipping of finished compost to customers. Most of the trucks used for waste collection in Vientiane were donated by Japan International Cooperation Agency

(JICA), and many of the trucks owned by trucking companies are imported, used trucks. The prices of used 5 tonne trucks were investigated at three used car dealerships, and the average price was used in the analysis. Chinese, Russian and Japanese trucks are between $7,500 and $13,000. The used trucks sold in Vientiane are usually 5 years old. According to truck owners and drivers, the trucks are commonly used for 10 to 15 years depending on travel distance and maintenance condition. Based on this information, the truck lifetime was assumed to be 10 years, and the replacement cost was incorporated into the total capital costs as with other equipment. The truck cost for organic waste collection was not considered in the decentralized composting plants because the plants were assumed to be sited close enough to the markets for the waste to be moved by carts.

2.2.4 Operation and maintenance costs

2.2.4.1 Salaries

The number of staff at a facility should be first appraised to estimate the total salary. The required number of people to operate a facility was derived based on the facility capacity. Considering an 8 hour work day, 4 or 5 full time workers are needed to process 1 tonne of waste (SANDEC and Waste Concern, 2001). Therefore, the following operators are the least required:

- Centralized composting facility; 5 tonnes × 4 workers/tonne = 20 workers
- Decentralized composting facility; 1.25 tonne × 4 workers /tonne = 5 workers

In addition, one supervisor, one office worker, one truck driver, and two waste collectors would be needed with exceptions explained in the following paragraph. The number of waste collectors was based on an interview with the Lao Garbage Service, a waste collection company.

Decentralized composting plants would not need a truck driver because it is not necessary to collect organic waste by a truck due to the proximity to the source. In the case of decentralized plants at the markets (Alternative 4), the supervisor and the office worker were excluded as well. The current market managers and office clerks at each market can be used for these duties. Market managers stated that they would want to employ waste collectors from current staff such as market cleaners because they are part-time workers. The salary of each position in this analysis reflects their present level in the local labour market. All operators, including the driver and the collectors, were assumed to be paid $50/month. The salary of an office worker is the beginning level for their position, and the same as the operators. A supervisor's salary is the same as the managers in fertilizer plants in the city, which is $100/month.

2.2.4.2 Utility bills

Utility bills were estimated based on the assumed utility consumption rates. The unit costs of utility consumption to consider in this study are as follows.

- Electricity $0.05/kWh
- Water $0.04/m^3
- Telephone $0.02/min

The electricity consumption rate as well as the telephone fee was calculated based on the utility expenditure of factories with a similar size to the composting facility. Water consumption rate was derived from the information acquired from the offices in the city, which averages 3m^3/month/capita. It was assumed that most of the water consumption resulted from workers in a facility, not during the composting process because collected run-off or leachate will be recycled on the site for the processing. However, the centralized composting facility outside the city was assumed not to pay for water usage because most of industries located outside the city utilize groundwater for free.

In a decentralized facility near the markets, electricity use was assumed to be the same as the larger centralized ones since electricity is mainly consumed in an office which has the same number of staff and office equipment.

2.2.4.3 Tools and supplies

Several hardware shops at different area markets were visited to examine the prices of shovels, rakes, plastic cover sheets, water hoses, hand carts, gloves, boots, masks and so on. The average value of the prices was applied as a unit cost of each component. The unit cost of uniforms involves fabric prices and tailoring because uniforms usually are tailored, not ready made in Vientiane. The number of tools and some supplies such as shovels, rakes and uniforms was estimated based on the number of workers and lifetime, ranging from one month to six months depending on the items. The cost of each item was calculated using;

$$\text{Costs for tools or supplies} = \text{unit cost} \times \text{number of units in a year}$$
$$= \text{unit cost} \times (\text{No. of workers}) \times (\text{purchase frequency in a year})$$

Clothing items are doubled in frequency because spares of these items are needed for laundering. Other supplies such as bags and plastic cover sheets were estimated based on the composting capacity and size of the processing area. The size of bags to fill with finished compost is 10 kg, and each bag is purchased at 5 cents.

$$\text{Cost for bags} = \text{unit cost} \times \text{number of bags in a year}$$
$$= \$0.05/\text{bag} \times \left(\frac{\text{amounts of finished compost (kg/year)}}{\text{10kg per bag}} \right)$$

2.2.4.4 Land rent

Land rental payment falls into O&M costs when the facility rents the land, instead of purchasing it. In this study, only land rent was investigated for land acquisition due to high land prices in the city. However, the facility outside the city was assumed to have no land rental cost because the site would be donated by the Vientiane municipality. According to the Department of Domestic and Foreign Investment, the land lease of prime areas costs from $\$0.5/m^2$/year to $1.0/m^2$/year for industrial land. It was found through interviews that the Sikhai market, near the airport, pays $\$1.0m^2$/year, and the Khuadin market, in downtown area, pays $\$1.4/m^2$/year for the sake of the use of government lands. These two markets are two of the four markets to consider in this study. The rent price of $\$1.4/m^2$/year was used for the estimation of annual land rental cost in this study since three out of the four markets in question are located near the centre of Vientiane.

$$\text{Land rental cost} = \$1.4/m^2/\text{year} \times \text{total site area } (m^2)$$

2.2.4.5 Disposal of rejects

Waste feedstock for composting may contain materials not decomposable. Also, the final product may retain materials not composted. Such rejects would be removed during sorting and screening processes, and sent to the landfill. The amount of rejects is 13% of total waste input by weight (SANDEC and Waste Concern, 2001). The disposal fee is a landfill tipping fee, which is $1/tonne.

$$\text{Disposal cost} = \$1.00/\text{tonne} \times \text{input waste (tonne/year)} \times 13\%$$

2.2.4.6 Truck operation and maintenance for shipment to compost sites

Truck operation and maintenance costs are accrued to transport separated organic waste at the markets to a composting site. These costs involve fuel cost, parts replacement, regular checks, repairs and other accessories, and activities to keep a truck running. The truck driver's wage was included in the category of salaries. The costs were appraised through interviews with truck drivers, truck owners, and waste collection companies. Fuel cost is $0.11/km given the fuel efficiency of 5km/L and fuel price of $0.53/L for a 5 tonne truck. Truck maintenance cost is $0.13/km. Therefore, the costs were estimated depending on the travel distances of a truck. The distances were measured on the city map, and doubled to calculate round trip distances. The travel distances are 50 km, and 10 km per round trip from the plant outside the city, and in the city, respectively. This distance includes the distance between each market the truck visits. It was assumed that two trips per day are required to collect organic waste from the four markets.

$$\begin{aligned}\text{Truck O \& M Costs} &= \text{fuel cost} + \text{truck maintenance cost} \\ &= \$0.11/\text{km} \times \text{travel distance(km/year)} + \$0.13/\text{km} \times \text{travel distance(km/year)}\end{aligned}$$

Decentralized composting plants have no truck O&M costs. The plants need no truck for organic waste transportation since they were assumed to be sited near or within the markets.

2.2.4.7 Shipping of compost and rejects

Shipping cost incorporates shipping of the compost to customers and transportation of rejected waste to the landfill. The centralized facilities can use their own truck, and the decentralized can commission a waste collection company for the shipment of rejects to the landfill. The transportation cost of rejects was derived from the following equations.

$$\text{Transportation cost of rejects from the centralized facility} = \$0.24/\text{km} \times \text{travel distance (km/year)}$$

$$\text{Transportation cost of rejects from the decentralized facility} = \$0.33/\text{km} \times \text{travel distance (km/year)}$$

The unit cost was calculated on the basis of the assumption that the 5 tonne truck is fully loaded. It is the sum of fuel and truck maintenance costs. The difference of the unit cost between two options is due to the truck operator's incentive. Truck drivers in the waste companies have an allowance per trip. Currently, the Lao garbage Service charges $13/trip with a 5 tonne truck, which is $0.33/km given the one round trip distance of 40 km.

To estimate the shipping cost of compost, it was assumed that the final product was delivered to nursery shops in the city. One nursery market was found in Vientiane. 15% of waste feedstock is converted to compost according to the mass flow study in Dhaka (SANDEC and Waste Concern, 2001). When it comes to the shipping of compost from decentralized facilities, the cost is $0.06/tonne/km, which is the set by Laotian government. Centralized facilities expend on shipping of compost the same unit cost as the transportation of rejects because their own truck are used.

2.2.4.8 Others

Composting plants need amendments such as manure and rice bran to balance the C/N ratio of compost, enhancing compost quality. Bat dung and cow dung are commonly used as manure in organic fertilizer plants in Vientiane. The cost of amendments was predicted at between $0.03/tonne and $0.08/tonne according to interviews at organic fertilizer plants. Therefore, the cost was calculated by the equation below.

Cost for amendment = $0.03 or $0.08/tonne × amounts of amendment required (tonne/year)

2.2.5 Benefits

Two types were considered in order to calculate the benefits of composting. One was revenue from the sale of compost, and the other was cost savings from landfill disposal and waste transportation.

2.2.5.1 Revenue

The main source of the benefits of composting is the sale of finished compost product. The price of compost was estimated based on the current fertilizer price in the city. Chemical fertilizers are sold at between $0.06/kg and $0.08/kg at nurseries, and organic fertilizers are sold directly to farmers at a price ranging from $0.05/kg to $0.06/kg. Therefore, the selling price of compost was approximated at $0.06/kg. SANDEC and Waste Concern (2001) reported that the compost price was about $0.05/kg, and in India, the final compost product price ranged from $0.04/kg to $0.05/kg (Hoornweg, D. *et al.*, 1999). The assumed compost price in this study is slightly higher than in these two countries, although the consumer prices depend on nations and time. A sensitivity analysis was carried out in chapter 4 to determine as to whether there is a possibility of a price reduction to increase market competition of the compost product. The total revenue was calculated as below. One tonne of organic waste produces about 0.15 tonne of compost (SANDEC and Waste Concern, 2001).

$$\text{Total revenue} = \$0.06/\text{kg} \times \text{total input waste (kg/year)} \times 15\%$$

2.2.5.2 Cost savings

The potential cost savings were incorporated into the estimation of benefits. There are two avoided costs to examine in this report associated with composting. First, composting reduces the need for landfill disposal by diverting organic waste to a composting facility. As a result, the landfill tipping fee, $1/tonne, is saved. Below is the equation to estimate the amount of money saved from less disposal.

$$\text{Cost saving from landfilling} = \$1.00/\text{tonne} \times \text{total waste diverted to a composting plant (tonne/year)}$$

Second, with composting, the city saves the transportation cost of waste depending on the distance between the landfill and the markets. One less trip to the landfill with a 5tonne truck saves $0.33/km. This value was calculated based on the current waste collection fee charged by garbage companies in the city, including fuel, truck maintenance costs and truck drivers' incentives. The equation is as follows.

$$\text{Cost saving from waste transportation} = \$0.33/\text{km} \times \text{total travel distance to the landfill (km/year)}$$

3. Costs and Benefits of the Composting Facilities[1)]

3.1 Alternatives of Composting Facilities

This project examines the costs and benefits of different alternatives, and evaluates the financial feasibility of each. Four alternatives were analyzed:

- A1: centralized composting facility outside the city
- A2: centralized composting facility in the city
- A3: decentralized composting facilities next to the markets
- A4: decentralized composting facilities within the markets

Alternative A1 was assumed to be sited outside Vientiane, specifically at the Vientiane landfill site. This landfill site is located 18 km from the city, and it is commonly referred to as KM18. Alternative A2 would be a facility in the city, near the Khuadin market, which is the downtown area, and it is one of candidates suggested by the municipality. This site was considered for the illustration purpose in the study to compare the composting costs depending on the distance between the centralized facility and the markets. Other available sites in the city could be equally considered. Figure 3.1 shows the location of the two centralized composting facilities. These two facilities have the same design specifications.

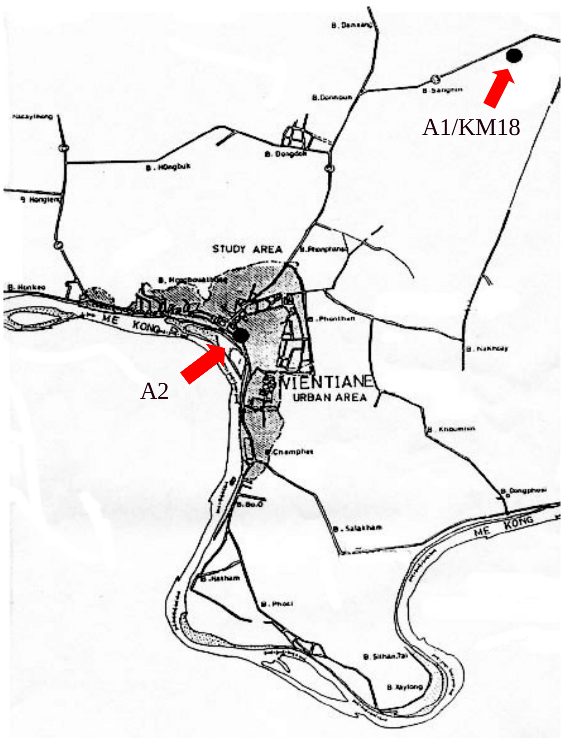

Figure 3.1 Location of the centralized composting alternatives

1) all the cost and benefit data for each alternative are provided with in both dollars and kips, in appendices 1-1a through 3-2.

Decentralized composting facilities at four different locations were also investigated. There are two options for decentralized facilities. Alternative A3 is decentralized facilities next to the markets, and A4 is decentralized ones right in the markets. Location of the four markets is mapped in figure 3.2. For alternatives A3 and A4, it was assumed that land is available near and within the four markets. The total capacity of the four decentralized facilities is equivalent to one centralized facility. The capacity of each decentralized facility is 1.25 tonne.

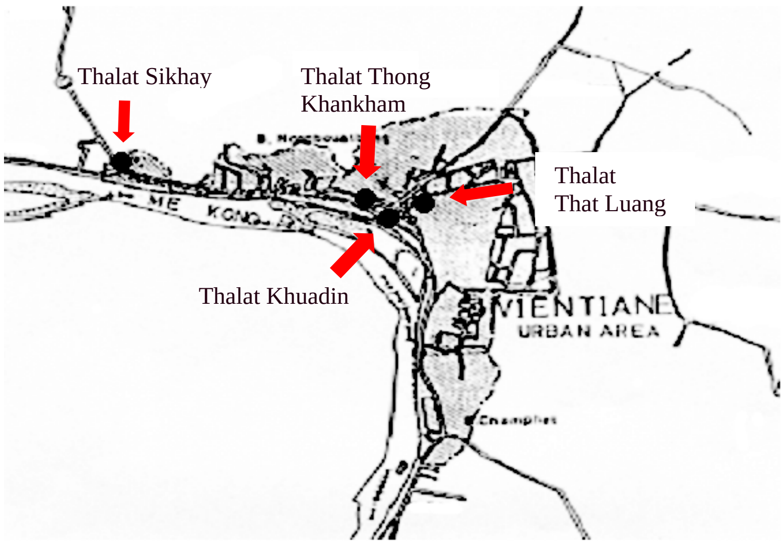

Figure 3.2 Location of the four markets for decentralized composting facilities

Total capital costs, operation and maintenance costs, and benefits are evaluated in the following sections in order to predict the profitability of each alternative. Net benefit was used to compare alternatives. Plausible choices between alternatives can be made based on this criterion.

3.2 A1: Centralized Composting Facility outside the City

3.2.1 Capital costs

Capital costs involve the facility construction, utility installations, and the equipment and truck purchase. There is no land cost because the site would be donated by the municipality in this case. Total capital costs come to about $48,800. The table 3.1 represents the details of the capital costs.

Table 3.1 Summary of capital costs of alternative A1

Components		Unit	Unit cost	No. of units	Total ($)
Facility construction					
Site preparation		$\$/m^2$	0.50	1000	500
Processing areas	Pad	$\$/m^2$	17.21	706	12,150
	Roof	$\$/m^2$	13.05	630	8,222
Water pond		$\$/m^2$	29.45	17	501
Office and machinery room		$\$/m^2$	159.00	30	4,770
Access road		$\$/m^2$	21.50	300	6,450
Drainage system		$/m	17.35	126	2,186
Fence		$/m	11.42	126	1,439
Electricity		$/unit	14.00	2	28
Waster supply (groundwater)		$/unit	299.00	1	299
Subtotal					**36,545**
Utility installation fees					
Electricity		$/unit	90.00	1	90
Water		$/unit	70.00	0	0
Telephone		$/unit	60.00	2	120
Subtotal					**210**
Equipment					
Shredder		$/ea	252.17	1	252
Water pump		$/ea	30.00	2	60
Office furniture		$/set	29.67	2	59
Office equipment		$/set	906.00	1	906
Subtotal					**1,277**
Truck		$/ea	10,750.00	1	**10,750**
Total cost		$			**48,782**
20 year amortization cost		$/year			**7,049**

Facility construction cost is estimated to be about $36,500, and utility installation fees would be $210 in total. The equipment and the truck would cost $1,280 and $10,750, respectively. As shown in figure 3.3, most of the capital cost would be the facility construction cost, which is 75% of the total.

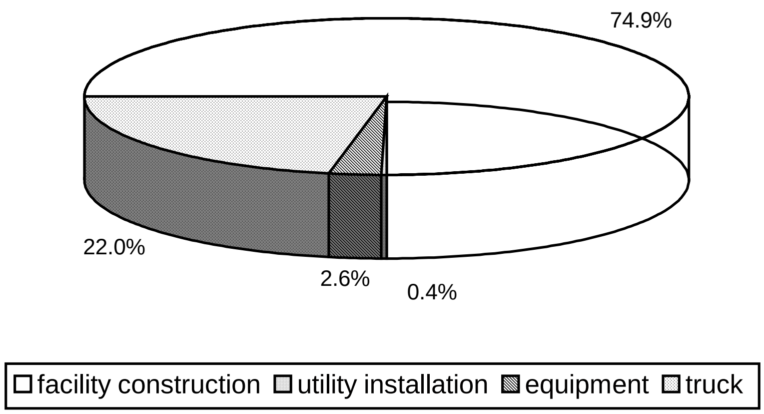

Figure 3.3 Proportion of each component of the capital costs for A1

Most of the facility construction costs are for paving and roofing of process areas. KM18 is accessed via the unpaved dirt road from the Highway 13, about 50 m from the highway to the fence. The paving of the access road costs over $6,400. This cost can be saved if the existing landfill road is shared. Utility installation fees are the service connection fees. Water installation fee was not considered in this option because this facility was assumed to use groundwater, not the local water supply service. Instead, the cost for groundwater development was estimated, which is approximately $300. Since the technology would be the labour intensive windrow composting system, not much in the way of the processing equipment is needed. The equipment for composting is shredders to chop bulk wastes and water pumps to recycle water on-site. Other equipment is office necessities, which contribute most of the equipment cost. The estimated price of the used 5 tonne truck, 5 years old, is $10,750. The expected lifetime of the truck is 10 years.

Annual capital cost is equivalent to $7,050/year when the total cost is amortized over 20 years with a 12% interest. However, the equipment and the truck were assumed to need replacement after 10 years, which would cost about $12,000. Therefore, this replacement cost was also incorporated into the capital cost. The amortized annual cost is derived from the following equation.

$$A = P\,(A \mid P\,12\%, 20) = \left[\$48{,}782 + 12{,}028(P \mid F\,12\%{,}10)\right](A \mid P12\%{,}20)$$
$$= (\$48{,}782 + \$12{,}028 \times 0.32197) \times 0.13388 = \$7{,}049$$

3.2.2 Operation and maintenance costs

Total operation and maintenance costs amount to $30,300/year. The largest portion of O&M costs is salary, which comes to $15,600 per year. It is half of the costs as described in figure 3.4. The required number of people is 25, involving 20 operators, one truck driver, 2 waste collectors, one supervisor and one office clerk. Each cost of the components are summarized in table 3.2.

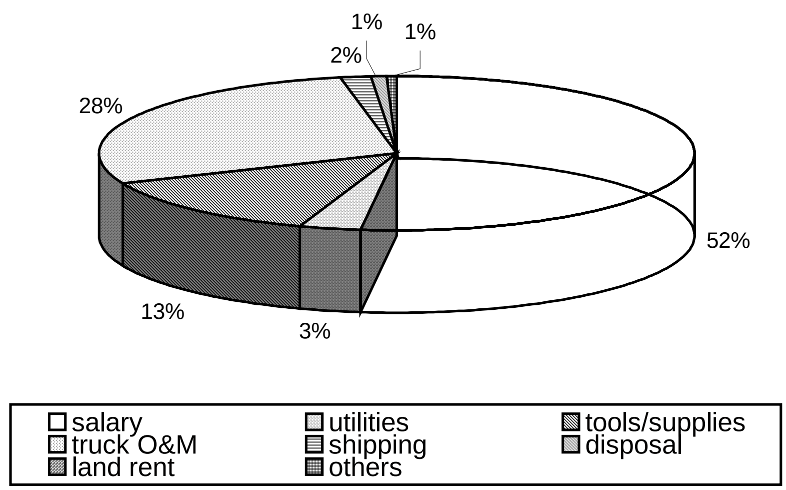

Figure 3.4 Proportion of each components of O&M costs for A1

There is no water cost in the utility bill because it was assumed the plant would use groundwater. Other industries around that area also use groundwater, and do not pay for water consumption. The electricity consumption rate is 800 kWh/month, which is equivalent to $480/year, and the telephone fee is $530/year based on 2,200 minutes of telephone calls every month. The time was estimated on the basis of average calls per person in the surveyed offices. Expendable tools and supplies cost over $4,000/year. The number of units is represented in table 3.2. Shovels and rakes are needed to turn the composting piles, and the numbers depend on the number of operators. The length of water hose is enough to reach all the processing areas from the water pond. The number of 10 kg bags is 75 per day in accordance with 750 kg/day of the finished compost. To cover the total curing area, 80 plastic cover sheets, with a width of 180 cm, are needed.

Table 3.2 Summary of operation and maintenance costs of alternative A1

Components	Unit	Unit cost	No. of units/year	Annual cost ($)
Salaries				
Supervisor	$/cp.	100.00	1×12	1,200
Other staff	$/cp.	50.00	24×12	14,400
Subtotal				**15,600**
Utility bills				
Electricity	$/kWh	0.05	800×12	480
Water	$/m^3	0.04	0	0
Telephone	$/min	0.02	2,200×12	528
Subtotal				**1,008**
Tools and supplies				
Shovels, rakes etc.	$/ea			816
Bags	$/ea	0.05	75/d×365	1,369
Clothing (uniforms etc.)	$/ea			1,822
Subtotal				**4,007**
Truck O&M				
Fuel	$/km	0.11	100km/d×365	4,015
Maintenance	$/km	0.13	100km/d×365	4,745
Subtotal				**8,760**
Shipping of compost and rejects				
Shipping of compost	$/km	0.24	40km/w×52	499
Shipping of rejects	$/km	0.24	2km/w×52	25
Subtotal				**524**
Disposal of rejects	$/tonne	1.00	0.65t/d×365	**237**
Amendments*	$/kg			**186**
Total cost	$/year			**30,322**

* including manure (bat dung or cow dung) and rice bran

Truck operation and maintenance costs were annually estimated at over $8,700. This cost includes fuel and all other maintenance costs, and it depends on the travel distance along with the number of trips. The travel distance of one trip is 50 km on average. The distances between markets are incorporated into the total distance along with the distance from the markets to the facility. The more a truck travels, the more the cost increases. Therefore, to reduce this cost, it would be better to fill the truck fully with separated organic waste. Shipping cost of the compost product and waste rejects comes to over $500/ year. To save the shipping cost, transportation is made once a week with the 5 tonne truck full every time. This cost also depends on the distance traveled. The round trip distance to the nursery in the downtown area is 40 km, and to the landfill cell currently operated is about 2 km. The disposal cost of rejects is estimated at $240/year given that 650 kg of waste is rejected every day, which is 13% of waste feedstock.

There is no land rental payment. Other costs include amendments such as manure and rice bran. This component costs $190/year, and is a very small portion of the O&M costs.

3.2.3 Benefits.

The composting plant creates around $27,900 of benefit every year as represented in table 3.3.

Table 3.3 Summary of benefits of alternative A1

Components	Unit	Unit value	No. of units/year	Total ($/year)
Revenue				
Sale of compost	$/kg	0.06	750kg/d×365	16,425
Subtotal				**16,425**
Cost savings				
Landfill disposal	$/tonne	1.00	5t/d×365	1,825
Waste transportation	$/km/trip	0.33	40km/trip×2×365	9,636
Subtotal				**11,461**
Total	$/year			**27,886**

The calculation of total benefits is quite straightforward as explained in section 2.2.5. The revenue generated from the sale of compost comes to $16,425/year. There is also benefit from the cost savings. Everyday, 5 tonnes of organic waste are diverted from the landfill, and this diversion saves a total of $11,500/year. First, the cost avoided from landfill disposal reaches $1,825/year when 5 tonne/day of waste are diverted, with the landfill tipping fee of $1/tonne. In addition, the composting facility saves the cost of waste transportation to the landfill. Two truck trips per day are avoided from the existing collection system for the four markets, and this trip reduction saves over $9,600 every year given the distance of 40 km per round trip.

The benefits are mainly created from the sale of compost with the selling price of $0.06/kg as shown in figure 3.5. More cost is saved from the waste transportation rather than the landfill disposal cost. The saving from less landfilling is only 7% with the low tipping fee of $1/tonne. Even neighbour country Vietnam charges at least $2/tonne according to the Vientiane landfill manager. The facility would save more cost from the waste disposal if the tipping fee increases.

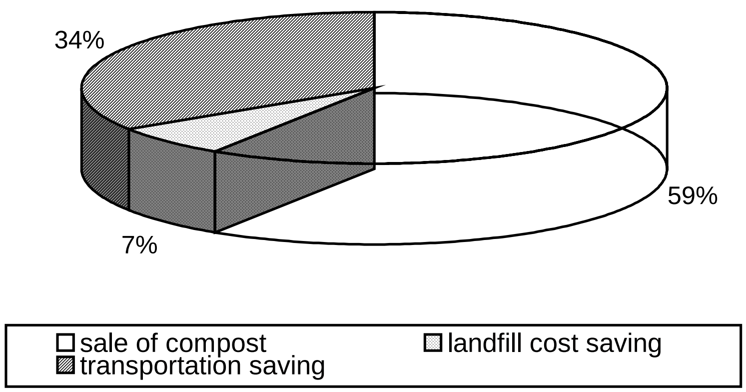

Figure 3.5 Proportion of each component of benefits for A1

3.3 A2: Composting Facility in the City

Alternative A2 is also a centralized composting plant, and it would be located in a downtown area, as explained in section 3.1. The analysis of this site shows the effect of the distance between organic waste sources and the composting plant.

3.3.1 Capital costs

In A2, the construction cost is almost the same as for A1, amounting to about $36,200. The difference between these two alternatives is because this site needs no groundwater development, thus no cost for it.

Instead, water is served by the local supplier. The water installation fee is $70. Other costs are all the same in both alternatives. As a result, the total capital costs amount to about $48,500, and there is not much difference in comparison with the first option. The amortized annual cost is $7,019 over 20 years with a 12% interest rate. Table 3.4 summarizes the components of capital costs and the estimated costs of components.

Table 3.4 Summary of capital costs of alternative A2

Components		Unit	Unit cost	No. of units	Total ($)
Facility construction					
Site preparation		$/m^2	0.50	1,000	500
Processing areas	Pad	$/m^2	17.21	706	12,150
	Roof	$/m^2	13.05	630	8,222
Water pond		$/m^2	29.45	17	501
Office and machinery room		$/m^2	159.00	30	4,770
Access road		$/m^2	21.50	300	6,450
Drainage system		$/m	17.35	126	2,186
Fence		$/m	11.42	126	1,439
Electricity		$/unit	14.00	2	28
Waster supply (groundwater)		$/unit	299.00	0	0
Subtotal					**36,246**
Utility installation fees					
Electricity		$/unit	90.00	1	90
Water		$/unit	70.00	1	70
Telephone		$/unit	60.00	2	120
Subtotal					**280**
Equipment					
Shredder		$/ea	252.17	1	252
Water pump		$/ea	30.00	2	60
Office furniture		$/set	29.67	2	59
Office equipment		$/set	906.00	1	906
Subtotal					**1,277**
Truck		$/ea	10,750.00	1	**10,750**
Total		$			**48,553**
20 year amortization cost		$/year			**7,019**

In both centralized alternatives, the facility construction cost contributes most of the capital costs, and the design specifications are the same regardless of the location. In addition, there is no transportation cost for construction material within 25 km from the city according to construction companies. For these reasons, there is not much difference in the facility construction cost, resulting in the almost same capital costs. Therefore, it is noted that the site location little affects the capital cost.

3.3.2 Operation and maintenance costs

In this alternative, the operation and maintenance costs amount to $24,800/year in total. The salary paid, in total, is $15,600/year, which is the same amount as in the first option. Other costs are also the same except the transportation cost. In addition, land rental cost is added to the O&M costs. The details of operation and maintenance costs in the second alternative are represented in table 3.5.

Table 3.5 Operation and maintenance costs of alternative A2

Components	Unit	Unit cost	No. of units/year	Annual cost ($)
Salaries				**15,600**
Utility bills				
Electricity	$/kWh	0.05	800×12	480
Water	$/m^3	0.04	75	36
Telephone	$/min	0.02	2,200×12	528
Subtotal				**1,044**
Tools and supplies				**4,007**
Land rent	$/m^2	1.40	1,000	**1,400**
Truck O&M				
Fuel	$/km	0.11	20km/d×365	803
Maintenance	$/km	0.13	20km/d×365	949
Subtotal				**1,752**
Shipping of compost and rejects				
Shipping of compost	$/km	0.24	5km/w×52	62
Shipping of rejects	$/km	0.24	40km/w×52	499
Subtotal				**561**
Disposal of rejects	$/tonne	1.00	0.65t/d×365	**237**
Amendments	$/kg			**186**
Total cost	$/year			**24,787**

As shown in figure 3.6, transportation cost is 9% of the total. This portion is much smaller than the portion in A1. The transportation cost comprises the truck operation and maintenance costs and the shipping cost. The truck operation and maintenance cost amounts to about $1,750/year. Total truck travel distance per trip is 10 km. The shipping cost for compost and waste rejects is $60/year and $500/year, respectively, given that the frequency is once a week. The truck is driven 5 km to deliver the compost to nursery shops in the city, and 40 km to the landfill. The average travel distance is much shorter than the distance in A1. All the distances represented here are round trip distance from the composting facility. The assumed rental fee is $1.4/m^2/year, and total land rent of $1,400 is paid each year.

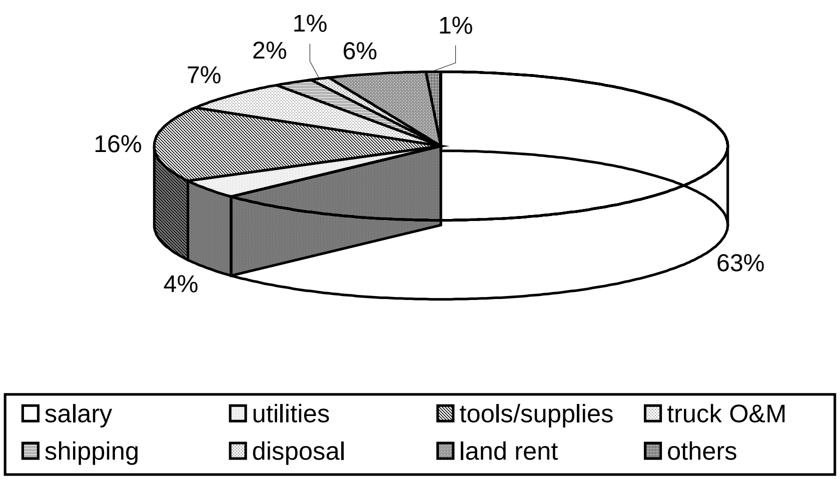

Figure 3.6 Proportion of each component of O&M costs for A2

3.3.3 Benefits

Benefits are exactly the same as the first alternative because the same amount of compost is produced, and the same amount of waste is diverted. The revenue generates $16,400 of the facility income, and also the facility saves $11,500 from the waste transportation and landfill disposal.

3.4 A3: Decentralized Composting Facilities near the Markets

Four decentralized composting plants are considered in this section. It was assumed that the four plants have all the same elements of facility design, workers, and utility consumption.

3.4.1 Capital costs

In alternative A3, the facilities have different design specifications from the first two alternatives as described in table 3.6.

Table 3.6 Summary of capital costs of alternative A3

Components		Unit	Unit cost	No. of units /site	Cost/site ($)	Total ($)
Facility construction						
Site preparation		$/m^2	0.50	250	125	
Processing areas	Pad	$/m^2	12.75	139	1,772	
	Roof	$/m^2	11.45	149	1,706	
Water pond		$/m^2	29.45	3	88	
Office and machinery room		$/m^2	159.00	30	4,770	
Access road		$/m^2	21.50	0	0	
Drainage system		$/m	17.35	63	1,093	
Fence		$/m	11.42	63	719	
Electricity		$/unit	14.00	2	28	
Subtotal					**10,301**	**41,204**
Utility installation fees						
Electricity		$/unit	90.00	1	90	
Water		$/unit	70.00	1	70	
Telephone		$/unit	60.00	1	60	
Subtotal					**220**	**880**
Equipment						
Shredder		$/ea	252.17	1	252	
Water pump		$/ea	30.00	2	60	
Office furniture		$/set	29.67	2	59	
Office equipment		$/set	897.50	1	898	
Subtotal					**1,269**	**5,076**
Total cost		$			**11,790**	**47,160**
20 year amortization cost		$/year				**6,533**

The facility size of one site is one fourth of the centralized facility. The size of each process area is proportionally decreased except the office building and machinery room. Other design specifications, pad and roof, are also different as discussed in section 2.2.3.2. As a result, the unit costs of paving and roofing are slightly lower than in A1 and A2. An access road is not needed because they are adjacent to the markets, where there exists a main road. Because the facilities are located at four different places, the cost of each component quantified in one place should be multiplied four times in order to estimate the total capital costs from the four. The estimated capital costs of the decentralized facilities are outlined in table 3.6.

The construction cost of one facility amounts to about $10,300, and the total cost for the four is about $41,200. Besides the construction cost, other components needed are the utility installation and the equipment. There is no need to purchase a truck because the facilities are located next to the markets. In total, the up-front cost for one facility is $11,800, and for four, comes to $47,200. This total amount is equivalent to an annual cost of $6,500 with 20 year amortization and 12% interest rate.

Figure 3.7 shows the fraction of each capital cost component. Because there is no truck purchase, the second largest expenditure, the construction cost highly contributes to the capital costs.

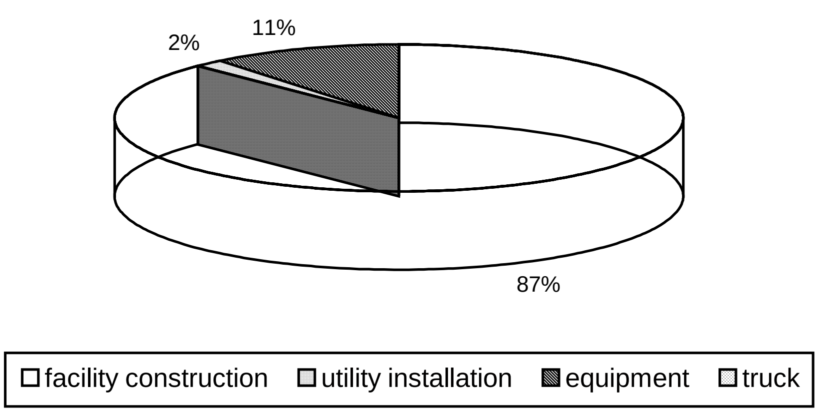

Figure 3.7 Proportion of components of the capital costs for A3

3.4.2 Operation and maintenance costs

The total operation and maintenance costs would amount to $37,300 every year for the four places. The estimated details are represented in table 3.7. The cost of one facility is quadrupled like the capital costs in section 3.4.1.

Table 3.7 Summary of operation and maintenance costs of alternative A3

Components	Unit	Unit cost	No. of units/year	Annual cost ($)
Salaries				
Supervisor	$/cp.	100.00	1×12×4	4,800
Other staff	$/cp.	50.00	8×12×4	19,200
Subtotal				**24,000**
Utility bills				
Electricity	$/kWh	0.05	800×12×4	1,920
Water	$/m^3	0.04	27×12×4	52
Telephone	$/min	0.02	800×12×4	768
Subtotal				**2,740**
Tools and supplies				
Shovels & rakes etc.	$/ea			2,336
Bags	$/ea	0.05	75/day×365	1,387
Clothing (uniforms etc.)	$/ea			2,217
Subtotal				**5,940**
Land rent	$/m^2/year	1.4	250×4	**1,400**
Shipping of compost and rejects				
Shipping of compost	$/km/tonne	0.06	6km/w×1.3t×52×4	97
Shipping of rejects	$/km	0.33	40km/w×52×4	2,746
Subtotal				**2,843**
Disposal of rejects	$/tonne	1.00	0.65t/d×365	**237**
Amendments	$/kg			**186**
Total cost	$/year			**37,346**

The salaries paid to the staff at each site were estimated to come to $6,000/year, and $24,000/year at all four sites. Each site was assumed to need nine people, which involves one supervisor, one office worker, five operators and two waste collectors. The utility bills of one facility would cost over $680/year, and, of four, $2,700/year. Electricity cost is the same as the centralized plants because of the reason explained in section 2.2.4.2. Other utility consumption rates were assumed to decrease according to the number of staff. Water and telephone fees decrease in proportion to the number of staff. The number of tools and supplies was also determined based on the number of workers.

There is no truck operation and maintenance costs because the facilities do not have a truck. Instead, pushcarts are purchased to move waste from the markets. It was assumed that compost and rejected waste were shipped by contracts. Compost is delivered by a local shipping company, and it costs $97/year in accordance with the frequency of once a week. The rejects are sent to the landfill by a waste collection company, which costs over $2,700/year. Land rental payment, disposal cost of rejects and other costs are the same as the centralized facilities in total.

3.4.3 Benefits

There is no difference in the benefits from the other alternatives.

3.5 A4: Decentralized Facilities within the Markets

3.5.1 Capital costs

This alternative has the same design specifications of the site as alternative A3 except that the facilities are sited within the markets, and there is no need to build a new office building. The market offices can be used. As a result, the facility construction cost is the same as for A3 excluding the office building cost. However, no construction cost for this building saves about $3,000 for each site, and $12,000 for four sites. In the utility installation fees, there would be no telephone installation fee because the telephones in the market offices can be shared. However, it was assumed that separate electricity and water connections were requested for the facilities. Office equipment would not be purchased either because the market offices already have this kind of equipment. Shredders and water pumps would be the necessary equipment. The capital costs are summarized in the following table 3.8. The total was estimated to come to $31,600, corresponding to $4,300/year.

Table 3.8 Summary of capital costs of alternative A4

Components		Unit	Unit cost	No. of units /site	Cost/site ($)	Total ($)
Facility construction						
Site preparation		$/m^2	0.50	250	125	
Processing areas	Pad	$/m^2	12.75	139	1,772	
	Roof	$/m^2	11.45	149	1,706	
Water pond		$/m^2	29.45	3	88	
Machinery room		$/m^2	159.00	12	1,908	
Access road		$/m^2	21.50	0	0	
Drainage system		$/m	17.35	63	1,093	
Fence		$/m	11.42	63	719	
Electricity		$/unit	14.00	2	28	
Subtotal					**7,440**	**29,760**
Utility installation fees						
Electricity		$/unit	90.00	1	90	
Water		$/unit	70.00	1	70	
Telephone		$/unit	60.00	0	0	
Subtotal					**160**	**640**
Equipment						
Shredder		$/ea	252.17	1	252	
Water pump		$/ea	30.00	2	60	
Subtotal					**312**	**1,248**
Total cost		$			**7,912**	**31,648**
20 year amortization cost		$/year				**4,291**

3.5.2 Operation and maintenance costs

This alternative does not need the supervisor, nor the office worker. The market managers and existing office workers can play these roles. In addition, waste cleaners in the markets are supposed to collect waste, which means no additional waste collectors. Therefore, only five new staff would be required at each composting facility, and $3,000 would be annually paid to them at each site, and $12,000/year at the four sites. The use of electricity would cost less than other alternatives because an office, main source of electricity consumption, would be shared in the markets. There would be an additional use of electricity caused by the composting equipment or the facility staff activity. The other difference from A3 is the cost of uniforms including masks, gloves and boots. This difference varies as a result of the number of operators. All other O&M costs are the same as A3. The number of units and total cost of each component are shown in table 3.9.

Table 3.9 Summary of operation and maintenance costs of alternative A4

Components	Unit	Unit cost	No. of units/year	Annual cost ($)
Salaries				
Operators	$/cp.	50.00	5×12×4	12,000
Subtotal				**12,000**
Utility bills				
Electricity	$/kWh	0.05	400×12×4	960
Water	$/m^3	0.04	27×12×4	29
Telephone	$/min	0.02	440×12×4	422
Subtotal				**1,411**
Tools and supplies				
Shovels & rakes etc.	$/ea			2,336
Bags	$/ea	0.05	19/d×365×4	1,387
Clothing (uniforms etc.)	$/ea			1,584
Subtotal				**5,307**
Land rent	$/m^2/year	1.4	250×4	**1,400**
Shipping of compost and rejects				
Shipping of compost	$/km/tonne	0.06	6km/w×1.3t×52×4	97
Shipping of rejects	$/km	0.33	40km/w×52×4	2,746
Subtotal				**2,843**
Disposal of rejects	$/tonne	1.00	0.65t/d×365	**237**
Amendments	$/kg			**186**
Total costs	$/year			**23,385**

3.5.3 Benefits

The benefits are the same as the other alternatives.

3.6 Comparison of Alternatives

The total costs and benefits of the four alternatives are compared in table 3.10, including annual net benefit. The alternatives are annotated as A1, A2, A3, and A4 in the table. A0 indicates the existing waste landfilling system as the reference. Since there is no composting facility in the existing system, it has a net benefit of zero. This figure is compared with the net benefit of the alternatives.

Table 3.10 Comparison of the alternatives (20 year amortization, 12% interest rate)

Components	A0	A1	A2	A3	A4
Capital cost ($)		48,782	48,553	47,160	31,648
Annual capital cost ($/year)		7,049	7,019	6,533	4,291
Cost per kilogram ($/kg)		0.03	0.03	0.02	0.02
O&M cost ($/year)		30,322	24,787	37,346	23,385
Cost per kilogram ($/kg)		0.11	0.09	0.14	0.09
Benefit ($/year)		27,886	27,886	27,886	27,886
Benefit per kilogram ($/kg)		0.10	0.10	0.10	0.10
Net benefit ($/year)	0	-9,486	-3,920	-15,993	210

A0 = existing system

A1 = centralized facility outside the city, A2 = centralized facility in the city

A3 = decentralized facilities next to the markets, A4 = decentralized facilities right in the markets

All the alternatives have negative values except A4. This means that only A4 is financially better than the existing system. However, the net benefit difference between A4 and A0 is a small amount, $200/year. This amount is much lower compared with a case of community based decentralized composting plant in Dhaka, Bangladesh (SANDEC and Waste Concern, 2001). Differences of the Dhaka study from this study involve the following: lower construction cost, probably due to different construction materials or design specifications, exclusion of land cost, and much cheaper labour cost. As well, in the Dhaka study, the following income and cost savings were incorporated: sale of recyclables, waste collection fee, reduced new landfill site purchase cost. In addition, The Dhaka study showed higher cost savings due to higher landfilling cost and waste transportation cost to the landfill.

The capital cost is almost same in all alternatives except A4, while the O&M cost varies depending on the alternative. Therefore, the net benefit difference between alternatives mainly results from this O&M cost. The bar graphs in figure 3.8 show the cost of components contributing to the O&M cost of each alternative. The most costly alternative is A3 because the same costs are repeated at all four sites. For example, four supervisors are a requisite because the facilities are operated separately, while the centralized facility needs only one supervisor. Likewise, A4 has the repeated cost items at all four sites, but, at the same time, it shares the existing market workers. Therefore, the cost is less than A3 as well as others. The capital cost of A4 is lowest as well since it shares the existing offices and office equipment in the markets.

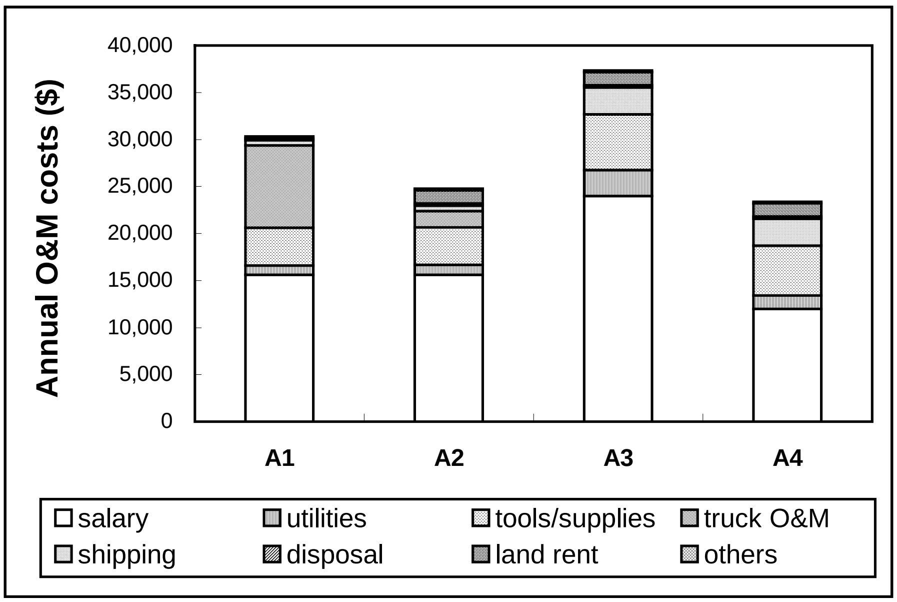

Figure 3.8 Cost of O&M components depending on the alternatives

The second least costly alternative is A2. This option has less expense on the truck operation and maintenance because of the relatively close distances between markets and the facility compared to A1, which is also a centralized composting plant. This cost is one fifth of the cost of A1. In contrast, A1 costs about $9,000/year for transportation. Thereby, this option is the second most expensive one even though there is no land cost, unlike the other alternatives. This option seems to be not feasible considering transportation cost.

There are some trade-offs between A2 and A4, which cost less than the other alternatives. Alternative A2 costs less in tools, supplies and shipping of compost and rejects, while A4 has no truck operation and maintenance costs and less salary. As a whole, A4 saves about $1,400/year to run the facility compared with A2. It indicates that the operation and maintenance cost savings can be more than from transportation and salaries.

The cost per kilogram of compost is summarized in the table 3.10 as well. The unit amortized capital cost ranges from $0.02/kg to $0.03/kg, and the operation and maintenance costs run from $0.08/kg to $0.14/kg. The total cost per kg of compost is higher than the assumed selling price of compost, $0.06/kg in the analysis. The benefit per kilogram is $0.1/kg, which is composed of $0.04/kg from cost savings, and $0.06/kg from sales. To sum up, A4 is the best in terms of the annual net benefit. However, these estimated values have uncertainties because of the assumptions made in the analysis. There may be changes in the relative difference of the annual net benefit depending on uncertain factors such as interest rate, facility lifetime, and compost price. Therefore, before finalizing the decision, further analysis is required, for example, sensitivity analysis. This will be discussed in chapter 4.

4. Sensitivity Analysis

The analyses in chapter 3 have uncertainties because the estimated parameter values are not known with certainty. As well, there would be possibilities of changes in certain factors in the future. Using different values for the factors would affect the measure of net benefit. Therefore, in this chapter, sensitivity analyses were conducted in order to investigate variation of the projected net benefits along with changes in key assumptions on which the net benefits are based. The effects of uncertainties in the following five key factors were investigated:

- interest rate
- amortization period (lifetime)
- total capital and operation and maintenance costs
- selling price of compost
- landfill tipping fee

Table 4.1 shows the "base case" results from chapter 3. The estimates in this table are the basic figures to compare with the results from the changes in the uncertain parameters. The sensitivity analyses in this chapter will make the financial analysis viable.

Table 4.1 Comparison of the alternatives (n = 20 years, r = 12%)

Components	A0	A1	A2	A3	A4
Capital cost ($)		48,782	48,553	47,160	31,648
Annual capital cost ($/year)		7,049	7,019	6,533	4,291
O&M cost ($/year)		30,322	24,787	37,346	23,385
Benefit ($/year)		27,886	27,886	27,886	27,886
Net benefit ($/year)	0	-9,486	-3,920	-15,993	210

A0 = existing system

A1 = centralized facility outside the city, A2 = centralized facility in the city

A3 = decentralized facility next to the markets, A4 = decentralized facility right in the markets

4.1 Changes in Interest Rate

Since the annual interest rate in the local banks in Vientiane fluctuates, as explained in section 2.2.3, interest rates, from a low of 8% to a high of 15%, were applied to analyze the effects of using different interest rates. The amortization period remains as 20 years. Interest rates affect the annualized capital costs, thereby changing the net benefit of each alternative. The results are provided in figure 4.1. As the interest rate increases, the net benefit proportionally decreases in all the alternatives. However, the differences between fours alternatives are affected only a little by interest rate changes. Only A4, with a rate of 12% or less results in a positive net benefit; the other alternatives have all negative values even at the lowest interest applied in this analysis.

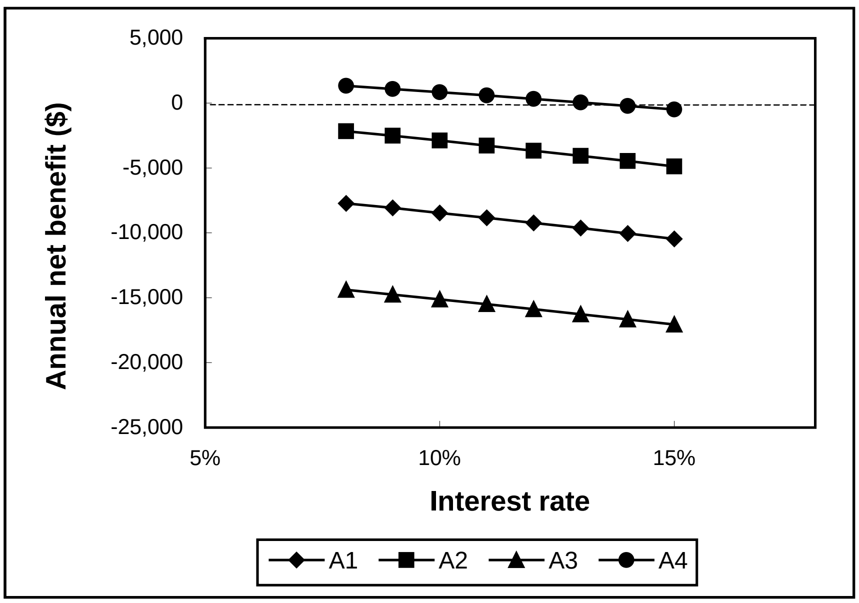

Figure 4.1 Annual net benefit of each alternative with the different interest rates

Tables 4.2 and 4.3 respectively give the detailed estimates with the lowest and the highest interest rates examined. In A1, the highest in capital cost, the capital cost increases about $2,700/yea as the interest rate increases from 8% to 15%. It shows that an extra one percent interest increases the annualized capital cost only about $390. Other alternatives have almost the same increase rate as A1, or less. Therefore, there is an indication that changes in interest rate do not greatly affect the overall results.

Table 4.2 Costs and benefits with an 8% interest rate and a 20 year amortization

Components	A1	A2	A3	A4
Capital cost ($/year)	5,536	5,513	5,043	3,282
O&M cost ($/year)	30,322	24,787	37,346	23,385
Benefit ($/year)	27,886	27,886	27,886	27,886
Net benefit ($/year)	-7,972	-2,414	-14,503	1,218

Table 4.3 Costs and benefits with a 15% interest rate and a 20 year amortization

Components	A1	A2	A3	A4
Capital cost ($/year)	8,268	8,232	7,735	5,106
O&M cost ($/year)	30,322	24,787	37,346	23,385
Benefit ($/year)	27,886	27,886	27,886	27,886
Net benefit ($/year)	-10,705	-5,133	-17,195	-605

4.2 Changes in Amortization Period

The amortization period affects annual capital costs. A 20 year amortization period for the facility was assumed in the previous basic analysis in chapter 3. In this section, amortization periods of 5 to 30 years were analyzed. However, the equipment and truck have a shorter lifetime than the facility site, and they needed replacement due to obsolescence. Therefore, it was assumed that their lifetime lasts a maximum of 10 years. The annual net benefits with 10 year and 30 year amortization are provided in table 4.4 and table 4.5 along with the costs and benefits of each alternative. The interest rate is 12% in all cases.

Table 4.4 Costs and benefits with 10 year amortization and 12% interest

Components	A1	A2	A3	A4
Capital cost ($/year)	8,634	8,593	8,347	5,601
O&M cost ($/year)	30,322	24,787	37,346	23,385
Benefit ($/year)	27,886	27,886	27,886	27,886
Net benefit ($/year)	-11,070	-5,494	-17,807	-1,101

Table 4.5 Costs and benefits with 30 year amortization and 12% interest

Components	A1	A2	A3	A4
Capital cost ($/year)	6,691	6,663	6,123	3,995
O&M cost ($/year)	30,322	24,787	37,346	23,385
Benefit ($/year)	27,886	27,886	27,886	27,886
Net benefit ($/year)	-9,128	-3,564	-15,583	506

When the capital costs are distributed over 10 years as in table 4.4 or 20 years as in table 4.1, the difference ranges from $1,300 to $1,800 depending on the alternatives. It is likely that the longer the amortization period is, the smaller the difference in cost is. Figure 4.2 provides a clear picture of this trend. The rate of the annual net benefit increase decreases as the period increases, although the net benefit increase continues as the amortization period increases. Therefore, a longer amortization does not increase the annual net benefit in proportion. A longer period will also increase the interest payment. Compared with the net benefit of the existing system, $0, the annual net benefit of A4 becomes positive with an amortization period of a little less than 20 years. Other alternatives all have negative value despite the increased amortization period.

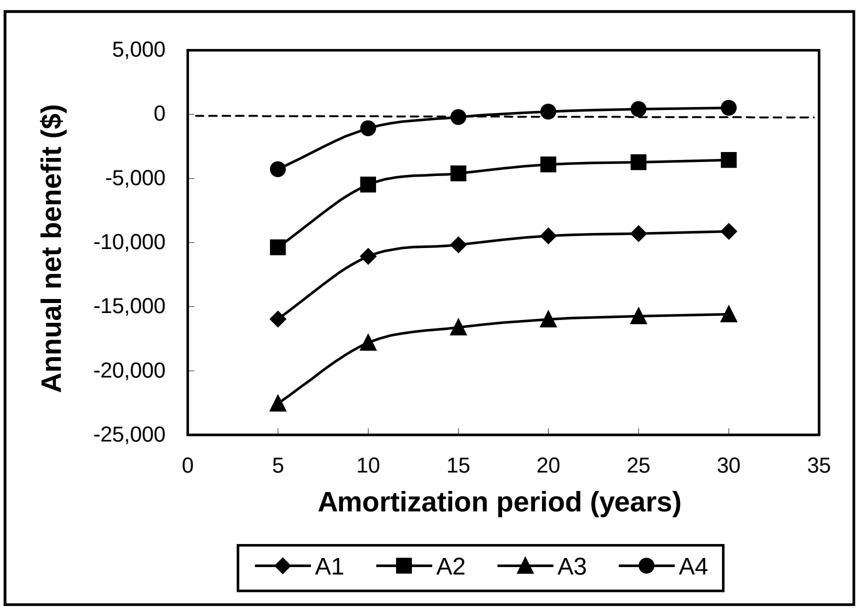

Figure 4.2 Changes in net benefit of each alternative according to amortization period

4.3 Changes in Interest Rate and Amortization Period

In this section, both interest rates and amortization period were changed to examine the combined effects. The tabulation of net benefit with various combinations is given in table 4.6. The results show little change in the ranking of the alternatives. However, the changes in both factors are more effective in changing the net benefit than the individual variation of the factors. Four cases produce profits, which are represented in bold in the table. They are all decentralized facilities within the markets. As expected, all alternatives have the highest annual net benefit with an 8% interest rate and 30 year amortization.

Table 4.6 Changes in combinations of interest rate and amortization period

Combination		Annual net benefit ($)			
		A1	A2	A3	A4
10years	8%	-9,706	-4,137	-16,488	-216
	12%	-11,070	-5,494	-17,807	-1,101
	15%	-12,156	-6,575	-18,857	-1,805
20years	8%	-7,972	-2,414	-14,503	**1,218**
	12%	-9,486	-3,920	-15,993	**210**
	15%	-10,705	-5,133	-17,195	-605
30years	8%	-7,494	-1,938	-13,955	**1,614**
	12%	-9,128	-3,564	-15,583	**506**
	15%	-10,431	-4,860	-16,881	-378

4.4 Changes in Total Capital Costs and O&M Costs

To investigate the possible relative saving effect of capital costs and O&M costs, these costs were changed within ±10%. The results are summarized in table 4.7. The O&M cost variance exceeds the capital cost change. The O&M costs vary from $2,300/year to $3,700/year, while the changes in the capital cost range from $430/year to $700/year.

Different combinations for annual net benefit are also reported in table 4.7. All the combinations with a 10% reduction of O&M costs have higher net benefits than other combinations. This result also supports the idea that operation and maintenance costs affect the net benefit more than amortized capital costs. In addition, A4 has all positive net benefit when the O&M costs are saved by 10%. Therefore, in order to increase the net benefit, it will be more effective to save O&M costs. For example, the salaries, the largest fraction of O&M costs, may be saved by increasing efficiency of workers.

Table 4.7 Changes of capital costs and O&M costs within 10% (n = 20years, r = 12%)

Change rate (%)		Annual value ($)			
		A1	A2	A3	A4
Capital cost	-10	6,344	6,317	5,879	3,862
	0	7,049	7,019	6,533	4,291
	+10	7,754	7,721	7,186	4,720
O&M costs	-10	27,290	22,308	33,611	21,047
	0	30,322	24,787	37,346	23,385
	+10	33,355	27,266	41,081	25,724
Benefit		27,886	27,886	27,886	27,886
Net benefit	0/0*	-9,486	-3,920	-15,993	**210**
	+10/0	-10,191	-4,621	-16,646	-219
	-10/0	-8,781	-3,218	-15,339	**639**
	0/+10	-12,518	-6,398	-19,727	-2,129
	0/-10	-6,453	-1,441	-12,258	**2,548**
	+10/+10	-13,223	-7,100	-20,380	-2,558
	+10/-10	-7,158	-2,143	-12,911	**2,119**
	-10/+10	-11,813	-5,696	-19,074	-1,700
	-10/-10	-5,749	-739	-11,605	**2,977**

* change rate of total capital cost/O&M cost

Of all the combinations, the three results are plotted in figure 4.3: 10% decrease in both capital and O&M costs, no change, and 10% increase in both. The variance of net benefit is larger than with previous factors.

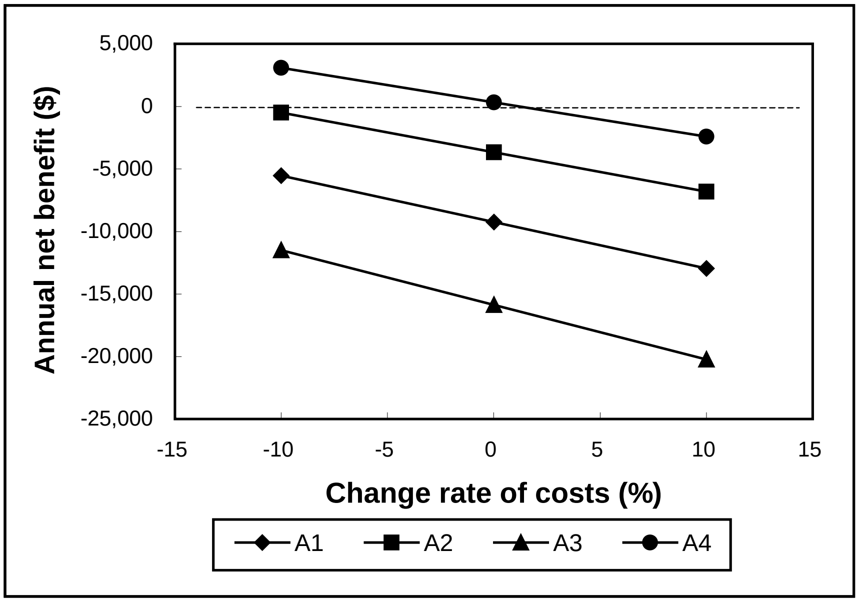

Figure 4.3 Changes in annual net benefit within a 10% cost variance

4.5 Changes in the Price of Compost

The selling price of compost is one of the key assumptions in this study. Therefore, changes in the price were studied in this section. Figure 4.4 illustrates that how the annual net benefit changes with the various prices of compost. The higher the price is, the higher the annual net benefit. The relative difference between alternatives, however, changes little. In order for composting to be financially feasible, compost would need to sell for at $0.06/kg with alternative A4, and at higher prices with the other alternatives. A one cent increase in the price generates over $2,700/year in revenue. The selling price, however, should not be too expensive compared with the chemical or organic fertilizer used in Laos. The price of fertilizers ranges from $0.05/kg to $0.08/kg. The compost with an expensive price will lose to competition in the area markets.

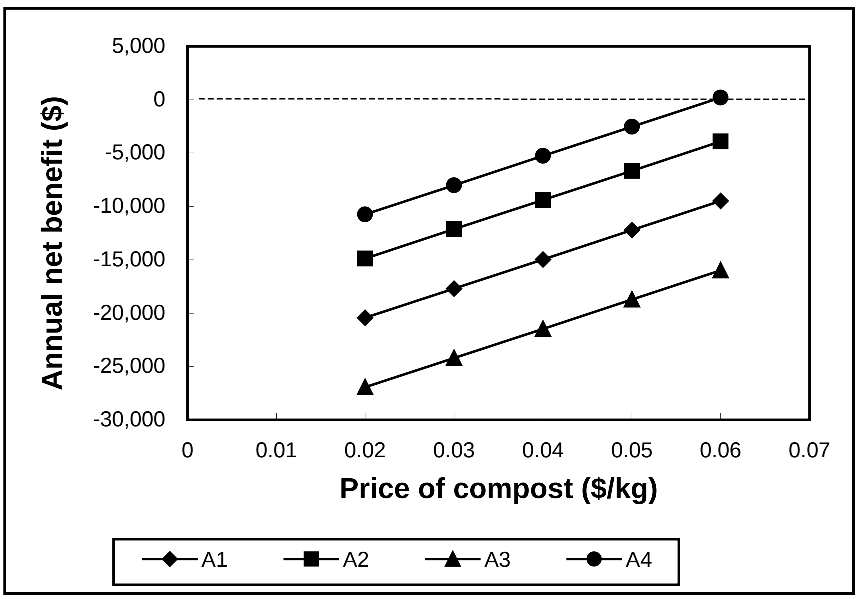

Figure 4.4 Annual net benefits varied with the price of compost

The least costly alternative (A4) was further analyzed to see what potential there might be to decrease the selling price of compost. Annual net benefits with decreased costs were examined along with the basic condition (20 year amortization and 12% interest). These were analyzed with 30 year amortization and 8% interest, and with 10% reduction in both capital and O&M costs. The selling price can decrease to about $0.05/kg as demonstrated in figure 4.5 when total costs are reduced by 10%. This price is slightly lower than chemical fertilizer, but it is the same as the cheapest organic fertilizer. Therefore, it may not be a very competitive price. As well, because the marketability of the compost product is yet uncertain in Vientiane, composting plants may not expect income from the product sale at this price.

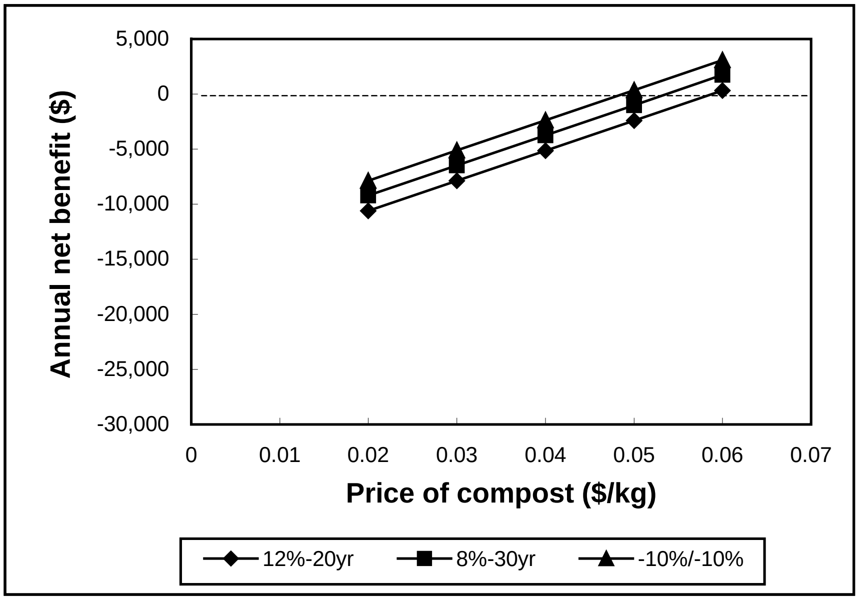

Figure 4.5 Annual net benefit varied with the price of compost in different combinations

4.6 Changes in the Landfill Tipping Fee

Currently, the Vientiane landfill charges one dollar per tonne of waste as a tipping fee. The landfill manager mentioned that the landfill budget needed to be doubled to manage the site properly. Vientiane may need to increase the tipping fee as the city continues to expand, and it generates more waste. Figure 4.6 shows the effect of a tipping fee increase on the net benefit of the alternatives. With a fee of $3/tonne, the best alternative A4 has a net benefit of $3,900/year. This net benefit is higher than that of a 10% cost reduction in section 4.4. Therefore, an increase in the landfill tipping fee creates high net benefits for composting plants due to the increase in cost saving from waste disposal fee. In addition, if other costs such as a development of a new landfill site are incorporated into the waste disposal cost, the total benefit will be higher although a long term plan may be required to experience this benefit.

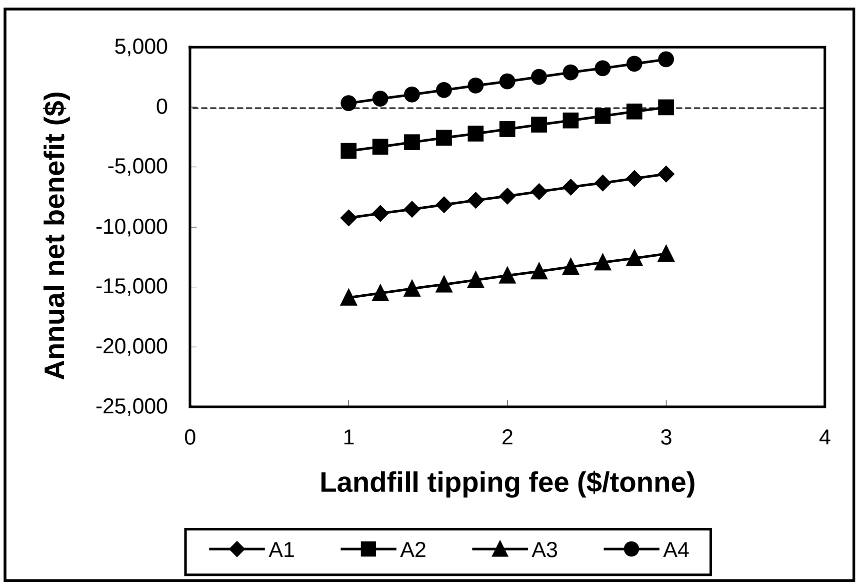

Figure 4.6 Changes in the annual net benefit according to landfill tipping fee

4.7 Multiple Combinations

The individual effect of five factors on the net benefit was previously examined. The net benefit fluctuated according to changes in each uncertain factor. In this section, the worst and the best combinations were assumed for the alternatives, and the results are compared in figure 4.7. Table 4.8 presents the conditions in each scenario. Total capital cost changes of ±10% were not considered in this analysis because the changes in interest rate and amortization period have more effect on the capital costs.

For the worst set of assumed values, none of the alternatives generate profit. Therefore, the composting program would not be financially feasible under this situation. On the other hand, with all the best conditions studied above, A2 and A4 have positive net benefits. A1 and A3 show a negative balance even with the best set of values

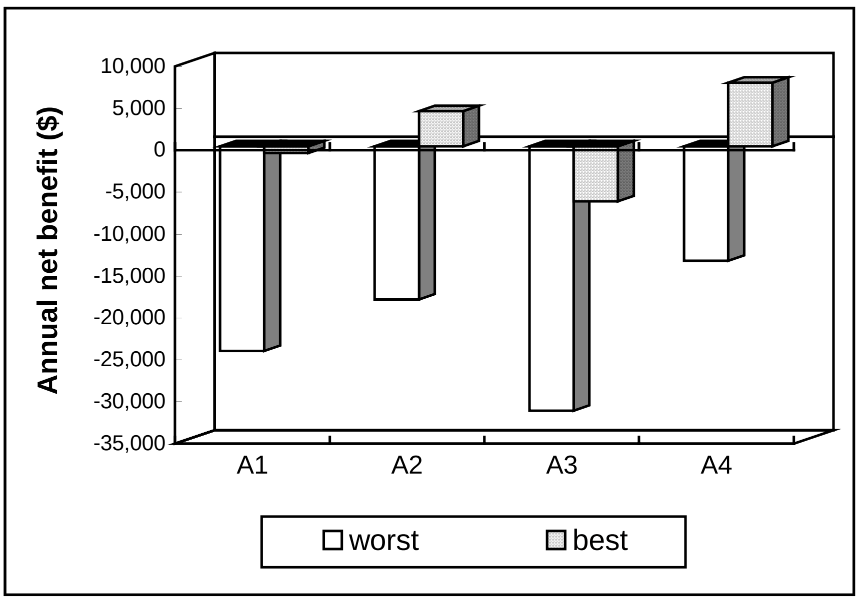

Figure 4.7 Changes in the net benefit by multiple choices of uncertain factors

Table 4.8 Details of multiple choices

	Substance
Worst scenario	15% interest, 10 year amortization, 10% O&M costs increase, $0.02/kg compost price, $1/tonne landfill tipping fee
Best scenario	8% interest, 30 year amortization, 10% O&M costs reduction, $0.06/kg compost price, $3/tonne landfill tipping fee

5. Summary, Conclusions and Recommendations

This study was conducted to evaluate whether composting market waste is feasible from a financial perspective. This chapter summarizes the result of the financial analysis in chapters 3 and 4. In addition, the chapter provides conclusions derived from the analysis including recommendations. This information may be useful for other areas, which are in a similar socio-economic situation as Vientiane.

5.1 Summary of the Financial Analysis

Costs and benefits of a 5 tonne composting facility were analyzed with four alternatives: a centralized composting plant outside the city (A1), a centralized composting plant in the city (A2), decentralized composting plants near the four markets (A3), and decentralized composting plants within the four markets (A4). Sensitivity analysis was also carried out.

5.1.1 Cost-benefit estimate

Costs and benefits quantified for each alternative are summarized in table 5.1. The annual capital costs were calculated based on 20 year amortization (facility lifetime) and 12% interest (average local bank interest rate in June, 2004).

Table 5.1 Summary of costs and benefits of market waste composting (n = 20 years, r = 12%)

Components	A1	A2	A3	A4
Capital cost ($)	48,782	48,553	47,160	31,648
Annual capital cost ($/year)	7,049	7,019	6,533	4,291
O&M cost ($/year)	30,322	24,787	37,346	23,385
Benefit ($/year)	27,886	27,886	27,886	27,886
Net benefit ($/year)	-9,486	-3,920	-15,993	210

The capital costs involve facility construction, utility installation, equipment and a truck purchase. The costs are almost same in all alternatives except A4. In A4, the site design is less sophisticated, and the market facility is shared. This situation reduces the construction cost, which mostly contributes to the capital cost. However, A3 costs nearly as much as the centralized composting facilities, A1 and A2, since some of the cost components such as an office building, and utility installation are reiterated at four sites, unlike A4, which shares the market facilities. The two centralized composing alternatives appear to have little difference in the capital cost, regardless that they are in different locations.

On the contrary, operation and maintenance costs are dependent on the alternatives examined. The main piece of O&M costs is salary, and A3 is the most expensive because of the cost duplication. The second largest portion of the O&M costs is tools and supplies, or waste transportation, depending on the alternatives. A4 shows the lowest cost in the site operation and maintenance, and it is followed by A2. Both alternatives expend less on transporting waste. A4 treats organic waste right at the source, therefore, the only transportation costs are to ship rejected waste and compost. In addition, A4 saves salary by sharing manpower with the markets, especially the administrative position. A2, which is closer to the markets, has a $6,500/year less transportation cost than A1, which is located an average 18km from the markets.

The benefits are mainly created from the sale of compost, which was assumed to be sold at $0.06/kg. There is a benefit of cost saving accruing from composting as well. More money is saved from the reduced transportation of waste rather than the avoided waste disposal fee at a landfill. Therefore, the proximity of a composting facility to the markets is an important element to increase the benefits. In addition, the reduced fuel consumption for transporting waste would lesson the environmental impacts caused by truck emissions, which was not factored in this analysis.

As a result, overall, A4 appears to be the financially best composting option in Vientiane. This alternative has the highest net benefit, and it is the only one better than the existing landfilling system.

5.1.2 Sensitivity analysis

Due to key assumptions made throughout the estimates, a sensitivity analysis was carried out. The effects of uncertainties in the following factors were examined: interest rate, amortization period, total capital and operation and maintenance costs, compost price, and landfill tipping fee. Table 5.2 shows the summary of the analyses, and the detailed results are provided in sections 4.1 through 4.8.

All the factors analyzed in this study result in changes in the net benefit of the four alternatives. Interest rate and amortization period changes have an influence upon the capital costs, changing the net benefit. The annual net benefit decreases as the interest rate increases, while increasing as amortization years increase. In the combinations of interest and amortization period changes, the combination of the lowest interest rate and the longest amortization period gives the best value. Interest rate is a more effective factor than amortization period if the period is longer than 10 years. The operation and maintenance costs are little affected by uncertain factors, except cost saving of any components of the O&M costs. The total benefits increase as the compost price or landfill tipping fee increases. It was noted that A4 was, at all times, the best alternative no matter what parameter was changed.

Table 5.2 Summary of the results of sensitivity analyses

Assumed value*	Annual net benefit ($)			
	A1	A2	A3	A4
Base case[1)]	-9,486	-3,920	-15,993	**210**
r[2)] = 8%, n[3)] = 30 years	-7,494	-1,938	-13,955	**1,614**
r = 15%, n = 10 years	-12,156	-6,575	-18,857	-1,805
10% increase in total costs	-12,518	-6,398	-19,727	-2,129
10% decrease in total costs	-5,749	-739	-11,605	**2,977**
$0.02/kg of compost price	-20,436	-14,870	-26,943	-10,740
$3/tonne of landfill tipping fee	-5,836	-270	-12,343	**3,860**

* Other values not given in each column are the same as the base case

1) 12% interest, 20 year amortization, $0.06/kg of compost price, and $1/tonne of landfill tipping fee

2) interest rate

3) amortization period

5.2 Conclusions

The following conclusions were derived from the result of the financial feasibility study of market waste composting in Vientiane. However, they should be cautiously applied to the decision making process as to the implementation of a composing program in Vientiane, as well as other areas in Laos, because of the site-specific alternatives and assumptions such as facility capacity, lifetime, and interest rate.

1. Estimates of capital costs are mainly determined by the facility construction cost when labour intensive low technology is used for composting, because there is not much need for processing equipment. Therefore, a less sophisticated and small design saves capital costs.

2. Capital costs have little relation to the location around the Vientiane area in the case of centralized composting facilities. The components in the capital cost are rarely affected by the distance. On the other hand, operation and maintenance costs depend on the traveled distances.

3. In the operation and maintenance costs, salaries and organic waste transportation costs are important factors influencing the total costs. Therefore, to make composting financially feasible, it is better to site the facility closer to the markets, the source of organic waste. It would also be beneficial to avoid extra workers, and to hire more part-time workers or volunteers rather than full time operators. At the same time, however, This would be considered as a social loss of creation of employment opportunities.

4. The alternative with decentralized composting facilities within each market (A4) is the best option in terms of the net benefit, although it is relatively small. This is because of the low landfill tipping fee ($1/tonne) and high salaries.

5. The centralized composting facility outside the city (A1) and decentralized facilities near the markets (A3) have negative financial net benefits even with the best conditions in the given ranges. From a financial perspective, it is not recommended to implement a composting plant for market waste outside the city, nor off-site decentralized composting plants.

6. The results from the sensitivity analyses indicate that there are changes in the net benefit by changing the uncertain factors, however there is little change in the ranking of the alternatives. This supports the conclusion that decentralized facilities within the markets (A4) is the best alternative, regardless of uncertainties.

7. The combination of interest rate and facility lifetime has more influence on the capital costs than a single factor. The compost price and the landfill tipping fee affect the benefits, and also they are the most influential factors in the net benefit. Decentralized facilities within the markets (A4) are financially more feasible with an increased compost price, higher tipping fee, lower interest rate, or longer amortization period.

5.3 Recommendations

Based on the findings of the financial analysis, it would be recommended for the Vientiane municipality to promote decentralized composting facilities within the markets (A4). In addition, in order for market waste composting to be more viable, it would be recommended to consider the following:

1. There is a need to increase the low landfill tipping fee. This increased fee would encourage the markets to participate in the composting programme. It would also improve the landfill management practices. In addition, some of the equipment considered in this study may not be needed, saving the capital costs. Community involvement such as volunteer work in composting facilities would be encouraged, as well. However, the Vientiane municipality should commission a further study to determine social implications of this involvement.

2. On-site decentralized composting plants may be favourable to the city considering a possibility of insecure revenue or the failure of the composting process. It would be better for the municipality to implement a decentralized facility at one site, and expand it to other sites when the program is successfully carried out. This initiation with a small facility can reduce the risk of failure of the composting programme.

3. The best alternative, decentralized composting facilities within the markets (A4), can provide more economic benefits, when viewed on a much larger scale. Therefore, indirect environmental benefits and other positive external benefits need to be internalized in the analysis, for example, extended landfill lifetime and reduced harmful environmental effects by avoiding organic waste disposal at landfills. At the same time, negative environmental effects need to be estimated. An analysis of these larger economic aspects may provide more beneficial information to the Laotian Waste-Econ programme.

6. References

Asian Development Bank (2004, March 31). Signing ceremony for ADB grant project to clean up Vientiane's waste management. ADB News. Retrieved October 27, 2004, from http://www.adb.org /Media/Articles/2004/4677_Lao_PDR_cleaning_up_waste_management/default.asp

Central Intelligence Agency (2004). The world factbook 2004. Retrieved November 2, 2004, from http://www.cia.gov/cia/publications/factbook/geos/la.html

Centre for Integrated Agricultural Systems (2002). The art and science of composting: a resource for farmers and compost producers. University of Wisconsin-Madison

Chopra, S. (2004). Quantification and composition audit of waste generated at the early morning market in Vientiane, Lao PDR. Master of Engineering thesis, Department of Civil Engineering, University of Toronto

Curry, S. and Weiss, J. (1993). Project analysis in developing countries. St. Martin’s Press, London

Department of Domestic and Foreign Investment (DDFI) (2003). Cost of doing business in Lao PDR. Retrieved June 29, 2004, from http://www.invest.laopdr.org/cost.htm

Fuguitt, D. and Wilcox, S.J. (1999). Cost-benefit analysis for public sector decision makers. Quorum Books, Westport

Hoornweg, D., Thormas, L., and Otten, L. (1999). Composting and its applicability in developing countries. The World Bank Group

Map of Vientiane in figures 3.1and 3.2 source: Japan International Cooperation Agency (1992, August). The study on the solid waste management system improvement project in Vientiane, Final report, Vol.Ⅱ supporting report (1); present solid waste management. JICA

Nas, T.F. (1996). Cost-benefit analysis: theory and application. Sage publication, Thousand Oaks

Otten, L. (2001). Wet-dry composting of organic municipal solid waste: current status in Canada. Canadian Journal of Civil Engineering, **28**(Suppl. 1), pp124~130

Riggs, J.L, Rentz, W.F, and Kahl, A.L (1982). Essentials of engineering economics. MaGraw-Hill, Toronto

SANDEC and Waste Concern (2001, June). Assessment of a decentralised composting scheme in Dhaka, Bangladesh; Technical, operational, organisational and financial aspects.

Szonyi, A., Fenton, R.G., White J.A., Agee, M.H., and Case, K.E. (2000). Principles of engineering economic analysis. Wall & Emerson, Toronto

United Nations Development Programme (2003, March 7). Company wants to sift through your trash. UNDP Lao PDR press releases. Retrieved June 21, 2004, from http://www.undplao.org /Press_release/trash.pdf

United Nations Development Programme (2004). Human development report 2004. Retrieved June 21, 2004, from http://hdr.undp.org/reports/global/2004/

Urban Research Institute (2004). Map of Vientiane, Vientiane

US EPA (1994, May). Composting yard trimmings and municipal solid waste. Retrieved May 12, 2004, from http://www.epa.gov/epaoswer/non-hw/compost/cytmsw.pdf

Waste-Econ (2004). About Waste-Econ. Retrieved October 27, 2004, from http://www.utoronto.ca /waste-econ/abo-was.html

Watkins, T., (2004). Introduction to cost-benefit analysis. Retrieved September 20, 2004, from http://www2.sjsu.edu/faculty/watkins/cba.htm

Wong, G. (2004). Analysis of separation options for composting market waste in Vientiane, Lao PDR. Master of Engineering thesis, Department of Civil Engineering, University of Toronto

World Bank Group (2004). World development indicators 2004. Retrieved October 27, 2004, from http://devdata.worldbank.org/data-query/

Appendices

Appendix 4. Data source to estimate cost-benefit components of a composting facility

Components		**Sources**
Capital costs		
Land		Department of Domestic and Foreign Investment (DDFI) website real estate agents
Facility construction	site preparation pad and roof of process area water pond office building machinery room access road, fence drainage system water supply	local construction companies Modern Home Co., Ltd. (856.21.241374~5) Toe (856.21.252642) Thipsoudaphone Pathana (Suanmon Village, Sisatanak District)
Utility installation	electricity/water/telephone	local suppliers (Electricity du Laos, Nampapa Lao, Lao Telecom)
Equipment	shredder, water pump, office furniture computer/printer air conditioner telephone	hardware shops near china markets (5)* furniture shops in sihoun village (3) local computer shops (4) appliance shops in the morning market (3)
Vehicles	trucks	used truck dealers (3)
O&M costs		
Salaries	supervisor office worker operators	interview with fertilizer plants (2), waste collection companies (2) DDFI website
Utilities	electricity/water/telephone	local suppliers
Tools and supplies	shovels, rakes, hoses, bags, sieves, hand carts, uniforms, gloves, boots etc.	hardware shops (5~6) near China markets, TKK market and That Luang market
Truck O&M	fuel repair and other maintenance	local gas stations, truck drivers or owners (9), and garbage companies
Land lease		market managers (3) DDFI website
Shipping	compost organic/inorganic waste rejected	shipping companies
Disposal of rejects	organic/inorganic waste rejected	landfill manager
Amendments	manure, rice bran	organic fertilizer plants (2)

Appendix 4. Data source to estimate cost-benefit components a composting facility (continues)

Components		Sources
Benefits		
Revenue	compost price	nurseries (4) and fertilizer plants (2)
Cost savings	landfill disposal fee transportation (waste collection)	landfill manager waste collection companies

* the number in brackets indicates the number of contacts.

Apendix 5 Financial analysis tables in chapters 3 and 4 with kips[1)]

Table 3.1 Summary of capital costs of alternative A1

Components		Unit	Unit cost	No. of units	Total (kip)
Facility construction					
Site preparation		kip/m^2	5,000	1,000	5,000,000
Processing areas	Pad	kip/m^2	172,100	706	121,502,600
	Roof	kip/m^2	130,500	630	82,215,000
Water pond		kip/m^2	294,500	17	5,006,500
Office and machinery room		kip/m^2	1,590,000	30	47,700,000
Access road		kip/m^2	215,000	300	64,500,000
Drainage system		kip/m	173,500	126	21,861,000
Fence		kip/m	114,200	126	14,389,200
Electricity		kip/unit	140,000	2	280,000
Waster supply (groundwater)		kip/unit	2,990,000	1	2,990,000
Subtotal					**365,444,300**
Utility installation fees					
Electricity		kip/unit	900,000	1	900,000
Water		kip/unit	700,000	0	0
Telephone		kip/unit	600,000	2	1,200,000
Subtotal					**2,100,000**
Equipment					
Shredder		kip/ea	2,521,700	1	2,521,700
Water pump		kip/ea	300,000	2	600,000
Office furniture		kip/set	296,700	2	593,400
Office equipment		kip/set	9,060,000	1	9,060,000
Subtotal					**12,775,100**
Truck		kip/ea	107,500,000	1	**107,500,000**
Total cost		kip			**487,819,400**
20 year amortization cost		kip/year			**70,493,200**

[1)] the tables in chapters 3 and 4 are duplicated with kips, and each table number corresponds to the same one as in chapters 3 and 4

Table 3.2 Summary of operation and maintenance costs of alternative A1

Components	Unit	Unit cost	No. of units/year	Annual cost (kip)
Salaries				
Supervisor	kip/cp.	100,000	1×12	12,000,000
Other staff	kip/cp.	500,000	24×12	144,000,000
Subtotal				**156,000,000**
Utility bills				
Electricity	kip/kwh	500	800×12	4,800,000
Water	kip/m^3	400	0	0
Telephone	kip/min	200	2,200×12	5,280,000
Subtotal				**10,080,000**
Tools and supplies				
Shovels, rakes etc.	kip/ea			8,161,500
Bags	kip/ea	500	75/d×365	13,687,500
Clothing (uniforms etc.)	kip/ea			18,211,400
Subtotal				**40,060,400**
Truck O&M				
Fuel	kip/km	1,100	100km/d×365	40,150,000
Maintenance	kip/km	1,300	100km/d×365	47,450,000
Subtotal				**87,600,000**
Shipping of compost and rejects				
Shipping of compost	kip/km	2,400	40km/w×52	4,992,000
Shipping of rejects	kip/km	2,400	2km/w×52	248,600
Subtotal				**5,241,600**
Disposal of rejects	kip/tonne	10,000	0.65t/d×365	**2,372,500**
Amendments*	kip/kg			**1,860,000**
Total cost	kip/year			**303,214,500**

* including manure (bat dung or cow dung) and rice bran

Table 3.3 Summary of benefits of alternative A1

Components	Unit	Unit value	No. of units/year	Total (kip/year)
Revenue				
Sale of compost	kip/kg	600	750kg/d×365	164,250,000
Subtotal				**164,250,000**
Cost savings				
Landfill disposal	kip/tonne	10,000	5t/d×365	18,250,000
Waste transportation	kip/km/trip	330	40km/trip×2×365	96,360,000
Subtotal				**114,610,000**
Total	kip/year			**278,860,000**

Table 3.4 Summary of capital costs of alternative A2

Components		Unit	Unit cost	No. of units	Total (kip)
Facility construction					
Site preparation		kip/m^2	5,000	1,000	5,000,000
Processing areas	Pad	kip/m^2	172,100	706	121,502,600
	Roof	kip/m^2	130,500	630	82,215,000
Water pond		kip/m^2	294,500	17	5,006,500
Office and machinery room		kip/m^2	1,590,000	30	47,700,000
Access road		kip/m^2	215,000	300	64,500,000
Drainage system		kip/m	173,500	126	21,861,000
Fence		kip/m	114,200	126	14,389,200
Electricity		kip/unit	140,000	2	280,000
Waster supply (groundwater)		kip/unit	2,990,000	0	0
Subtotal					**362,454,300**
Utility installation fees					
Electricity		kip/unit	900,000	1	900,000
Water		kip/unit	700,000	1	700,000
Telephone		kip/unit	600,000	2	1,200,000
Subtotal					**2,800,000**
Equipment					
Shredder		kip/ea	2,521,700	1	2,521,700
Water pump		kip/ea	300,000	2	600,000
Office furniture		kip/set	296,700	2	593,400
Office equipment		kip/set	9,060,000	1	9,060,000
Subtotal					**12,775,100**
Truck		kip/ea	107,500,000	1	**107,500,000**
Total		kip			**485,529,400**
20 year amortization cost		kip/year			**70,186,600**

Table 3.5 Operation and maintenance costs of alternative A2

Components	Unit	Unit cost	No. of units/year	Annual cost (kip)
Salaries				
Supervisor	kip/cp.	100,000	1×12	12,000,000
Other staff	kip/cp.	500,000	24×12	144,000,000
Subtotal				**156,000,000**
Utility bills				
Electricity	kip/kwh	500	800×12	4,800,000
Water	kip/m^3	400	75×12	360,000
Telephone	kip/min	200	2,200×12	5,280,000
Subtotal				**10,440,000**
Tools and supplies				
Shovels, rakes etc.	kip/ea			8,161,500
Bags	kip/ea	500	75/d×365	13,687,500
Clothing (uniforms etc.)	kip/ea			18,211,400
Subtotal				**40,060,400**
Land rent	kip/m^2	14,000	1,000	**14,000,000**
Truck O&M				
Fuel	kip/km	1,100	20km/d×365	8,030,000
Maintenance	kip/km	1,300	20km/d×365	9,490,000
Subtotal				**17,520,000**
Shipping of compost and rejects				
Shipping of compost	kip/km	2,400	5km/w×52	624,000
Shipping of rejects	kip/km	2,400	40km/w×52	4,992,000
Subtotal				**5,616,000**
Disposal of rejects	kip/tonne	10,000	0.65t/d×365	**2,372,500**
Amendments*	kip/kg			**1,860,000**
Total cost	kip/year			**247,868,900**

Table 3.6 Summary of capital costs of alternative A3

Components		Unit	Unit cost	No. of units /site	Cost/site (kip)	Total (kip)
Facility construction						
Site preparation		kip/m^2	5,000	250	1,250,000	
Processing areas	Pad	kip/m^2	127,500	139	17,720,000	
	Roof	kip/m^2	114,500	149	17,060,000	
Water pond		kip/m^2	294,500	3	883,500	
Office and machinery room		kip/m^2	1,590,000	30	47,700,000	
Access road		kip/m^2	215,000	0	0	
Drainage system		kip/m	173,500	63	10,930,000	
Fence		kip/m	114,200	63	7,194,600	
Electricity		kip/unit	140,000	2	280,000	
Subtotal					**103,021,600**	**412,086,400**
Utility installation fees						
Electricity		kip/unit	900,000	1	900,000	
Water		kip/unit	700,000	1	700,000	
Telephone		kip/unit	600,000	1	600,000	
Subtotal					**2,200,000**	**8,800,000**
Equipment						
Shredder		kip/ea	2,521,700	1	2,521,700	
Water pump		kip/ea	300,000	2	600,000	
Office furniture		kip/set	296,700	2	593,400	
Office equipment		kip/set	8,975,000	1	8,975,000	
Subtotal					**12,690,100**	**50,760,400**
Total cost		kip			**11,790**	**471,646,800**
20 year amortization cost		kip/year				**65,331,500**

Table 3.7 Summary of operation and maintenance costs of alternative A3

Components	Unit	Unit cost	No. of units/year	Annual cost (kip)
Salaries				
Supervisor	kip/cp.	1,000,000	1×12×4	48,000,000
Other staff	kip/cp.	500,000	8×12×4	192,000,000
Subtotal				**240,000,000**
Utility bills				
Electricity	kip/kWh	500	800×12×4	19,200,000
Water	kip/m^3	400	27×12×4	518,400
Telephone	kip/min	200	800×12×4	7,680,000
Subtotal				**27,398,400**
Tools and supplies				
Shovels & rakes etc.	kip/ea			23,356,000
Bags	kip/ea	500	75/day×365	13,870,000
Clothing (uniforms etc.)	kip/ea			22,170,400
Subtotal				**59,396,400**
Land rent	kip/m^2/year	14,000	250×4	**14,000,000**
Shipping of compost and rejects				
Shipping of compost	kip/km/tonne	600	6km/w×1.3t×52×4	973,440
Shipping of rejects	kip/km	3,300	40km/w×52×4	27,456,000
Subtotal				**28,429,440**
Disposal of rejects	kip/tonne	10,000	0.65t/d×365	**2,372,500**
Amendments	kip/kg			**1,860,000**
Total cost	kip/year			**373,456,740**

Table 3.8 Summary of capital costs of alternative A4

Components		Unit	Unit cost	No. of units /site	Cost/site (kip)	Total (kip)
Facility construction						
Site preparation		kip/m^2	500	250	1,250,000	
Processing areas	Pad	kip/m^2	127,500	139	17,720,000	
	Roof	kip/m^2	114,500	149	17,060,000	
Water pond		kip/m^2	294,500	3	883,500	
Machinery room		kip/m^2	1,590,000	12	19,080,000	
Access road		kip/m^2	215,000	0	0	
Drainage system		kip/m	173,500	63	10,930,500	
Fence		kip/m	114,200	63	7,194,600	
Electricity		kip/unit	140,000	2	280,000	
Subtotal					**74,401,600**	**297,606,400**
Utility installation fees						
Electricity		kip/unit	900,000	1	900,000	
Water		kip/unit	700,000	1	700,000	
Telephone		kip/unit	600,000	0	0	
Subtotal					**1,600,000**	**6,400,000**
Equipment						
Shredder		kip/ea	2,521,700	1	2,521,700	
Water pump		kip/ea	300,000	2	600,000	
Subtotal					**3,121,700**	**12,486,800**
Total cost		kip			**79,123,300**	**31,6493,200**
20 year amortization cost		kip/year				**42,910,000**

Table 3.9 Summary of operation and maintenance costs of alternative A4

Components	Unit	Unit cost	No. of units/year	Annual cost (kip)
Salaries				
Operators	kip/cp.	500,000	5×12×4	120,000,000
Subtotal				**120,000,000**
Utility bills				
Electricity	kip/kWh	500	400×12×4	9,600,000
Water	kip/m^3	400	27×12×4	288,000
Telephone	kip/min	200	440×12×4	4,224,000
Subtotal				**14,112,000**
Tools and supplies				
Shovels & rakes etc.	kip/ea			23,356,000
Bags	kip/ea	500	19/d×365×4	13,870,000
Clothing (uniforms etc.)	kip/ea			15,836,000
Subtotal				**53,062,000**
Land rent	kip/m^2/year	14,000	250×4	**14,000,000**
Shipping of compost and rejects				
Shipping of compost	kip/km/tonne	600	6km/w×1.3t×52×4	973,440
Shipping of rejects	kip/km	3,300	40km/w×52×4	27,456,000
Subtotal				**28,429,440**
Disposal of rejects	kip/tonne	10,000	0.65t/d×365	**2,372,500**
Amendments	kip/kg			**1,860,000**
Total costs	kip/year			**233,835,940**

Table 3.10 Comparison of the alternatives (20 year amortization, 12% interest rate)

Components	A0	A1	A2	A3	A4
Capital cost (kip)		487,819,400	485,529,400	471,646,800	316,493,200
Annual capital cost (kip/year)		70,493,200	70,186,600	65,331,500	42,910,000
Cost per kilogram (kip/kg)		260	260	240	160
O&M cost (kip/year)		303,214,500	247,868,900	373,456,740	233,835,940
Cost per kilogram (kip/kg)		1,110	910	1,360	850
Benefit (kip/year)		278,860,000	278,860,000	278,860,000	278,860,000
Benefit per kilogram (kip/kg)		1,020	1,020	1,020	1,020
Net benefit (kip/year)	0	-94,847,700	-39,195,500	-159,928,300	2,114,100

A0 = existing system

A1 = centralized facility outside the city, A2 = centralized facility in the city

A3 = decentralized facilities next to the markets, A4 = decentralized facilities right in the markets

Table 4.1 Comparison of the alternatives (n = 20 years, r = 12%)

Components	A0	A1	A2	A3	A4
Capital cost (kip)		487,819,400	485,529,400	471,646,800	316,493,200
Annual capital cost (kip/year)		70,493,200	70,186,600	65,331,500	42,910,000
O&M cost (kip/year)		303,214,500	247,868,900	373,456,740	233,835,940
Benefit (kip/year)		278,860,000	278,860,000	278,860,000	278,860,000
Net benefit (kip/year)	0	-94,847,700	-39,195,500	-159,928,300	2,114,100

A0 = existing system

A1 = centralized facility outside the city, A2 = centralized facility in the city

A3 = decentralized facilities next to the markets, A4 = decentralized facilities right in the markets

Table 4.2 Costs and benefits with an 8% interest rate and a 20 year amortization

Components	A1	A2	A3	A4
Capital cost (kip/year)	55,539,700	55,126,500	50,433,000	32,824,600
O&M cost (kip/year)	303,214,500	247,868,900	373,456,740	233,835,940
Benefit (kip/year)	278,860,000	278,860,000	278,860,000	278,860,000
Net benefit (kip/year)	-79,714,200	-24,135,400	-14,029,740	12,199,460

Table 4.3 Costs and benefits with a 15% interest rate and a 20 year amortization

Components	A1	A2	A3	A4
Capital cost (kip/year)	82,684,500	82,318,600	77,355,500	5,1056,500
O&M cost (kip/year)	303,214,500	247,868,900	373,456,740	233,835,940
Benefit (kip/year)	278,860,000	278,860,000	278,860,000	278,860,000
Net benefit (kip/year)	-107,039,000	-5,1327,500	-171,952,240	-6,032,470

Table 4.4 Costs and benefits with 10 year amortization and 12% interest

Components	A1	A2	A3	A4
Capital cost (kip/year)	86,336,300	85,931,000	83,474,000	56,014,300
O&M cost (kip/year)	303,214,500	247,868,900	373,456,740	233,835,940
Benefit (kip/year)	278,860,000	278,860,000	278,860,000	278,860,000
Net benefit (kip/year)	-110,690,800	-54,939,900	-178,070,740	-10,990,240

Table 4.5 Costs and benefits with 30 year amortization and 12% interest

Components	A1	A2	A3	A4
Capital cost (kip/year)	66,915,100	66,630,800	61,234,200	39,950,400
O&M cost (kip/year)	303,214,500	247,868,900	373,456,740	233,835,940
Benefit (kip/year)	278,860,000	278,860,000	278,860,000	278,860,000
Net benefit (kip/year)	-91,269,600	-35,639,700	-155,530,940	5,073,660

Table 4.6 Changes in combinations of interest rate and amortization period

Combination		Annual net benefit (kip)			
		A1	A2	A3	A4
10years	8%	-97,054,000	-41,637,100	-16,4886,000	-2,142,800
	12%	-110,690,800	-54,939,900	-178,070,740	-10,990,240
	15%	-121,553,500	-65,751,600	-188,573,340	-18,037,900
20years	8%	-79,714,200	-24,135,400	-14,029,740	**12,199,460**
	12%	-94,847,700	-39,195,500	-159,928,300	**2,114,100**
	15%	-107,039,000	-5,1327,500	-171,952,240	-6,032,470
30years	8%	-74,927,100	-19,378,000	-139,547,840	**16,159,060**
	12%	-91,269,600	-35,639,700	-155,530,940	**5,073,660**
	15%	-104,296,600	-48,602,300	-168,811,940	-3,764,240

Table 4.7 Changes of capital costs and O&M costs within 10% (n = 20years, r = 12%)

Change rate (%)		Annual value (kip)			
		A1	A2	A3	A4
Capital cost	-10	63,443,900	63,167,900	58,798,400	38,619,000
	0	70,493,200	70,186,600	65,331,500	42,910,000
	+10	77,542,500	77,205,200	71,864,700	47,201,000
O&M costs	-10	272,893,100	223,082,000	336,111,100	210,452,300
	0	303,214,500	247,868,900	373,456,740	233,835,940
	+10	333,536,000	272,655,800	410,802,400	257,219,500
Benefit		278,860,000	278,860,000	278,860,000	278,860,000
Net benefit	0/0*	-94,847,700	-39,195,500	-159,928,300	**2,114,100**
	+10/0	-101,897,000	-46,214,100	-166,461,400	-2,176,900
	-10/0	-87,798,400	-32,176,800	-153,395,100	**6,405,100**
	0/+10	-125,169,100	-63,982,400	-197,274,000	-21,269,500
	0/-10	-64,526,200	-14,409,600	-122,582,600	**25,497,700**
	+10/+10	-132,218,400	-71,001,000	-203,807,100	-25,560,500
	+10/-10	-71,575,500	-21,427,300	-129,115,800	**21,206,700**
	-10/+10	-118,119,800	-56,963,700	-190,740,800	-16,978,500
	-10/-10	-57,476,900	-7,389,900	-116,049,500	**29,788,700**

* change rate of total capital cost/O&M cost