

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

It is crucial to develop human society based on natural conservation. Concepts of sustainable development between economy and environment can help to identify the balance point. Managing waste effectively can contribute towards conservation development. It is necessary incorporate economic concepts in the environmental projects evaluation and management.

#### **2.2 The Needs of Sustainable Development**

According to Brundtland Commission (WCED, 1987), one of the well-known definitions of sustainable development is *sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It consists of two key concepts:*

- *The concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.*

Since decades ago, in order to achieve high speed development of economic and human society, missteps in consuming natural resources and managing the residues have already threatened all countries. The various global environmental issues cause serious consequences. The human society became to understand that the development and environment could not be separated since they have an inextricable linkage (WCED, 1987). Development definitely cannot exist via destroying natural resources. The economic development and natural environment are connected in a very complicated system of causes and effects.

Sustainable development appeals the use and management of natural resources in a wise way. One option is to balance the urbanization and MSW management, including disposal, reuse, recycle and reclaiming the resources. It is to avoid over-consumption of natural resources which are meant for next generations and to minimize the pollutions caused by continuous solid waste generation (Shekdar, 2009).

### **2.3 Waste Generation Trends**

MSW is normally considered as residential wastes, including commercial waste, household waste and waste generated from other sources (The World Bank, 1999; Agamuthu, 2001). The expansion of population and cities, leading to excessive consumption of natural resources, causes a large number of domestic wastes generated (Pratap *et al.*, 2011). The amount of MSW generation is affected by both the rate of economic development and Gross Domestic Product (GDP) (Shekdar, 2009; Agamuthu, 2004; Fauziah, 2010).

Socio-economic development can affect the trend of waste generation. Researches indicate that higher living standards society consume more resource, which leads to generation of larger amount of solid waste (Odum and Odum, 2006; Agamuthu, 2004; Fauziah, 2010). While the waste generation rate in under-developed nations is below 0.1 t/cap/yr (tonne /capital /year), in industrialized countries, this figure is over 0.8t/cap/yr (Bogner *et al.*, 2007).

According to a statistic by Global Exchange (2005), 73% of waste is generated from industrialized countries. For example, USA contributes the largest percentage (43.5%) among developed nations (Bogner *et al.*, 2007). Fortunately, some developed countries, like Denmark and Scotland, realized that recycling could reduce the waste disposal to landfills and invested several comprehensive recycling programs (Bogner *et al.*, 2007; Fauziah, 2010). These green activities contribute to the decrease in the amount of MSW in the industrialized regions.

Asia is a massive and diverse continent. It includes highly industrialized nations such as Japan and Singapore, as well as developing nations such as China and Malaysia. Asian Productivity Organization (APO) reported that urban regions generate larger amount of waste than that in countryside in Asia. It is stated that the municipal waste generation rate is above 1.0 kg/cap/day, while in rustic areas the rate is below 0.15 kg/cap/day (APO, 2007).

Because the proportion of urban populations is lower in under-developed and developing regions, the ratio of waste generation is much lower than that in high income Asian areas. It is reported that Hong Kong generates the most quantities of waste, and

construction waste occupies a large percentage of total waste generation amount (APO, 2007; Shekdar, 2009). Nepal being a low income country only generates 10% of Hong Kong's per capita waste generation with the most proportion consists of degradable components (Shekdar, 2002).

Developed nations have a higher proportion of recyclable materials compared with low GDP countries (Shekdar, 2002; Shekdar, 2009). The low percentage of recyclables in developing nations is ascribed to the market value of recycling system and policies (Shekdar, 2002; Shekdar, 2009; The World Bank, 1999). In some highly developed regions, many programs were started to reduce waste generation, and the target is to minimize the amount of waste disposing to landfills ultimately (Shekdar, 2002; Shekdar, 2009). Therefore, the rate of waste generation in well-controlled areas is slightly decreasing yearly (Poon, 2006; Shekdar, 2009).

In the high income areas, the data records on waste management are available and systemized which is benefited for planning and performing integrated waste management system (APO, 2007). In contrast, the information is limited in certain cities, in low income nations, because data are collected irregularly causing inefficient implementation of integrated waste management system (Shekdar, 2009).

Based on survey done by APO (2007), most Asian countries have put a number of investments in solving problems caused by waste generation. Nevertheless, some major issues are still suspended, like low technologies, lacking of policies and lacking of awareness in Asian developing areas (APO, 2007). Local authorities are suggested to

enhance the control of waste generation and apply an integrated MSW management system.

Malaysia has a total area of 329,847 km<sup>2</sup>. Due to rapid city expansion, average income growth and the consumption patterns resolution, the generation of MSW has increased over 91% during last decade in Malaysia (APO, 2007). Between 1996 and 2006, the daily average amount of waste generation increased from 13,000 tonnes to 19,100 tonnes in West Malaysia (Agamuthu *et al.*, 2009). In the rapidly developing cities, such as Kuala Lumpur, the per capita waste generation reached to 2.5 kg in 2006 (Agamuthu *et al.*, 2009; EPU, 2006). As other developing economies, the urban areas generate more waste compared with countrysides (Visvanathan *et al.*, 2006).

Based on the rate of waste generation by states from 1996 to 2005, the average growth rate of MSW generation in Peninsular Malaysia is around 2% annually (Zamali *et al.*, 2009). The amount of waste generation is increasing rapidly, which requires an efficient integrated waste treatment, disposal and management system in the future development (Zamali *et al.*, 2009).

Researches on quantification of solid waste are only available at local levels. Based on the data published by the Ministry of Housing and Local Government (MHLG) the amount of solid waste generation is above 18,000 tonnes per day in 2004 (Huszain, 2004). This figure excluded illegally disposal in drains and rivers (Huszain, 2004). Some of the industrial waste is not counted because some are recycled before entering the waste stream (Mohd Nasir, 2004). Since the database was not fully updated, Mohd

Nasir (2004) estimated that the recycling rate could be approximately 30% of total waste generation amount in Malaysia.

Rapid growth of MSW in decades already caused serious problems in Malaysia (Agamuthu, 2004). These problems include dirtiness of public parks and streets, frowziness of rubbish collection areas, unsystematic waste collection, illegal waste dumping sites, and low-efficiency solid waste management (Hassan, 2000). These impacts related to public health are more critical in large cities such as Kuala Lumpur and Penang (Hassan *et al.*, 1997; Fauziah, 2010). An integrated MSW management system including waste reduction, recycling and reusing is required, to improve the efficiency of solid waste management (Fauziah, 2010).

#### **2.4 The Needs of Sustainable MSW Management**

Sustainable waste management means using less landfills and larger amounts of recycling and composting approaches (Pearce *et al.*, 2000). Around 80% of MSW is recycled or reused, and the rest is sent to incineration system or dumped into landfills (Dawud *et al.*, 2011). Contrarily, only about 12% of waste is recycled in developing countries, and others are treated in unsustainable ways – buried or unsanitary dumps (Dawud *et al.*, 2011).

It is lack of awareness on environmental issues and improper waste disposal result in the threats of public safety and health. Thus, the MSW problem has changed to an inevitable necessity to be solved (Wath *et al.*, 2010). Air pollution, underground water pollution, soil erosion and deleterious insects and animals are the most significant

problems of improper solid waste disposal and management. Existing MSW system is close to be overloaded that effective models are urgently needed. MSW management should be designed that it balances between sustainable use of natural resources and reduction of waste disposal (Wath *et al.*, 2011).

## **2.5 Waste Characterization/Compositions**

The characteristics and the composition of waste is an important part in determining suitable the MSW management methods. Zamali *et al.* (2009) indicates that the waste compositions in Asian countries are quite different from that in Europe. Waste generated in industrialized nations comprises of large quantity of recyclables (such as paper and metal), and small portion of biodegradable waste (Fauziah, 2010).

Tropical solid waste from middle income areas mainly consists of 64% domestic waste, 25% industrial waste, 8% commercial waste and 3% of construction and institutional waste (APO, 2007). It is found that the percentage of organic waste always occupies a large number in developing nations with significant moisture content. In Malaysia, the general waste components are shown in Table 2.1.

Table 2.1 General Composition of Waste in Malaysia

Item No.	Waste Composition	Percentage by weight
1	Organic	47.0
2	Paper	15.0
3	Plastics	14.0
4	Wood, garden waste	4.0
5	Metal	4.0
6	Glass	3.0
7	Textile	3.0
8	Others	10.0

(Source: Huszain, 2004)

MSW from south-east Asian areas, the highly consists of putrescible waste such as food waste with high moisture level (Visvanathan *et al.*, 2003). On average, the humidity content of solid waste can be as high as 60-70% (Visvanathan *et al.*, 2003). It is also found that the waste density in Asia is over two times larger than that in western countries (Zerbock, 2003).

Types and density of waste can affect the effectiveness of waste treatment and disposal. Waste with higher density can be more efficiently disposed than that of lower density, while homogeneous waste normally is much easier to be treated in comparison of heterogeneous waste (Fauziah *et al.*, 2006). Low density waste – with big volume but light weight, has poor compressibility which affects the efficiency of waste disposal and waste utilization (Fauziah, 2010). It is suggested that MSW should be separated into different types before treating and disposing. To reduce the impacts of MSW disposal,



continuous efforts are required to be carried in achieving sustainable development (Zamali *et al.*, 2009).

## **2.6 General Status of Waste Management in Malaysia**

To achieve sustainable development, an effective waste management is important. Statistics by Abdul (2010) proves that the existing waste collection and disposal system does not allow the requirements of sustainable waste management in Malaysia. This is necessary since the types and qualities of solid waste are significantly different from one region to the other. The high moisture content (~70%) and mixed level of waste requires specific technologies and disposal management system according to local circumstances (Fauziah, 2010).

In Malaysia, MSW is under the responsibility of Ministry of Housing and Local Government (MHLG), which is one of three waste management departments (Latifah *et al.*, 2009). The other two are Department of Environment (DOE) and Ministry of Health (MOH). Schedule 1 hazardous waste are managed by DOE, and clinical waste management is under MOH (Latifah *et al.*, 2009).

Local authorities are responsible for MSW management under Local Government Act 1976, Section 72 (Latifah *et al.*, 2009). Latifah reported that more than 50% of income has been invested to MSW management by local governments. From 2007, over RM 1 billion of annual income has been budgeted for waste management (Fauziah and Agamuthu, 2006). However, the waste collection and waste transportation still have plenty of problems required to be solved as soon as possible. Half of the waste

management budget is used for waste collection, but only 76% of generated waste is collected (Latifah *et al.*, 2009). The implementation still could not prevent environment from depredating (Fauziah, 2010).

Starting from 1996, Malaysia MSW management had been privatised (Latifah *et al.*, 2009). Three main private authorized companies have formed respective operation zones – Alam Flora Sdn Bhd (central area), Southern Waste Management Sdn. Bhd. (southern area) and Idaman Bersih Sdn Bhd (northern area) (Latifah *et al.*, 2009). With the publication of Solid Waste and Public Cleansing Act 2007 and The Solid Waste and Public Cleansing Corporation Act 2007, a new structure was established under MHLG - Public Cleansing Management Corporation (PCMC) (Latifah *et al.*, 2009; Fauziah, 2010). This new corporation has the responsibility to help local governments to manage solid waste and monitor the concessionaires (Latifah *et al.*, 2009).

Like many Asian middle income nations, landfilling is the main final disposal method for MSW in Malaysia. However, only 3% of existing disposal sites is fully sanitary, while others are open dump sites or controlled dump sites (Fauziah, 2009). Most of these open dump sites have been overloaded (APO, 2007). Other current problems are poor management of landfills, lack of proper leachate treatment system and high cost of disposal (APO, 2007).

Open-dump sites occupy the largest percentage of Malaysian waste disposal sites (Fauziah, 2010). It doesn't have proper lining and leachate treatment facilities which can cause serious environmental threats (Moy *et al.*, 2008). It is recorded that harmful gases and untreated leachate has caused high contamination to air, water and soil in

some areas (Moy *et al.*, 2008). Improper disposal of MSW not only polluted the environment but also threatened the public health (Sharholy *et al.*, 2008). The accumulation of harmful components may cause some serious diseases such as cholera and cancers (Sharholy *et al.*, 2008).

The needs of proper design, construction and management of landfills are getting loose. To enhance waste management system especially waste disposal, the Malaysian Government try to improve the efficiency of landfills stage by stage. This concept was approved in Action Plan 1988.

The plan is targeted to up-grade all disposal sites into sanitary landfills with a proper leachate treatment system and gas collection facilities. In addition, the generated gases should be utilized to reduce air pollution, and landfills are supposed to be under effective management system (Latifah *et al.*, 2009). In 9<sup>th</sup> Plan, there are 4 main treatment facilities constructed in Malaysia.

- a) Taman Beringin Transferred Sataion in Kuala Lumpur treating 1700 tonnes of waste per day.
- b) Themal Treatment Plant in Labuan accepting 40 tonnes of waste per day.
- c) Selong Sanitary Landfill in Johor Bahru treating 1200 tonnes of waste per day.
- d) Bukit Tagar Sanitary Landfill in Hulu Selangor treating 1500 tonnes of waste per day.

Most of the existing landfills are filled up very quickly and get overloaded in a short time. More new landfills are required to be constructed due to the rapid waste generation. However, due to lack of financial and technical support, constructing new

landfills becomes more difficult (Fauziah, 2010; Fauziah *et al.*, 2006). Therefore, new landfills should have proper capacity planning, professional guidelines, and effective operation and management system. Before disposing waste into landfills, MSW should be controlled under appropriate waste collection, segregation and recycling projects (Fauziah, 2010; Fauziah *et al.*, 2006). It is necessary to enhance enforcement controls via regulations and rules, as well as to increase public awareness (Fauziah, 2010).

In Vision 2020, the government sets the targets to enhance the protection of environment and to apply ISWM system in the following decades (Latifah *et al.*, 2009). Waste recycling programs must be promoted in a well-organized way. Malaysia started waste recycling programs in 1993 (Latifah *et al.*, 2009). However, the low level of knowledge and awareness slowed the development of recycling programs. To improve the efficiency of recycling projects, the government has carried out a lot of efforts, such as drafting policies and supporting private companies.

In 2000, the MHLG restarted the recycling program and set November 11<sup>th</sup> to be the National Recycling Day (Latifah *et al.*, 2009). It is forecasted that the recycle rate can rise to 22% by 2020 (Latifah *et al.*, 2009). It means that at least one fifth of waste generated doesn't need to be sent off for disposal thus the life span of landfills can be extended. New advanced technologies are introduced from developed countries (Japan and Switzerland), which will highly improve the ability of waste treatment facilities and efficiency of MSW management in Malaysia (Abdul, 2010).

## **2.7 MSW Management**

MSW management becomes a challenge in Asian metropolis. A large portion of government investments are budgeted to this area in each city. The resources are getting tighter to meet the rapid growth of waste generation (Kamara, 2009). Managing MSW in an appropriate way has to be developed according to the local environment (APO, 2007).

### **2.7.1 Functions of Solid Waste Management**

The entire cycle of MSW consists of 6 mainly procedures mentioned in Chapter 1, which includes waste generation storage and collection, handling and separation waste, processing, final disposal (Rousta, 2008). These six main elements of solid waste management and interrelations can be indicated in Figure 2.1.

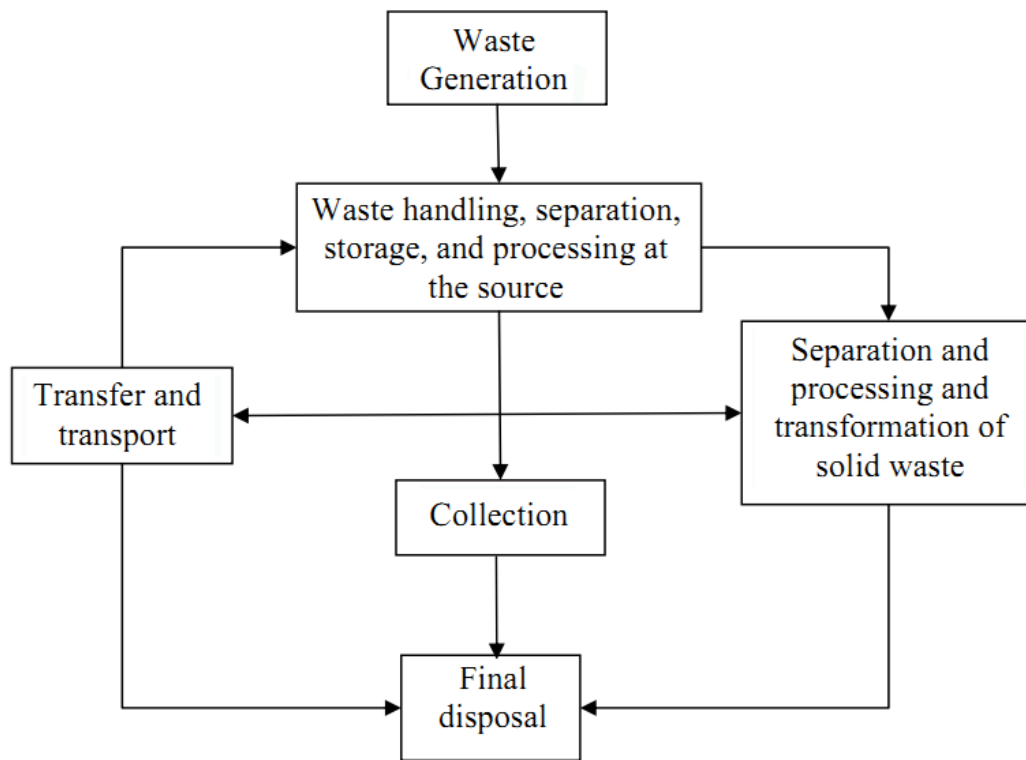


Figure 2.1 Functions and Interrelations of Elements in Solid Waste Management

(Source: Roustia, 2008)

MSW management is meant to balance the social economic development and protect living organism. Also it is to enhance public health and technological development.

## 2.7.2 Hierarchy of Waste Management

The hierarchy of waste management is an international instruction of setting the priorities of waste management practices (Gertsakis *et al.*, 2003). The objective of waste management hierarchy is to achieve the greatest environmental profits (UNEP, 2005). This hierarchy arranges the practices of waste management from most recommended to the least ones. Waste avoidance and reduction are the first options of waste management

practices. Figure 2.2 demonstrates the order of the elements within waste management hierarchy

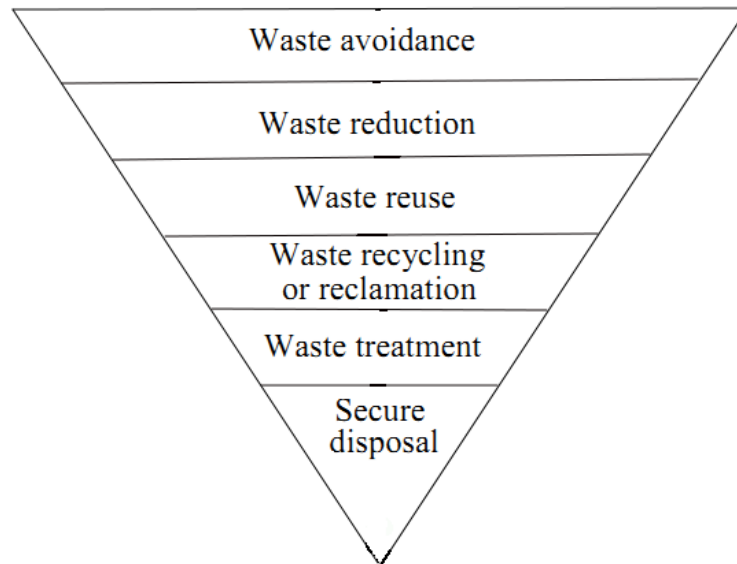


Figure 2.2: Hierarchy of Waste Management

(Source: Tchobanoglous *et al.*, 1993)

## 2.8 A Common Disposal Method –Landfill

According to the hierarchy of waste management, landfill use is considered as the last option due to its associated environmental impacts. In fact, all the waste ultimately needs a disposal site after pre-treatment, so landfills still play an important role in solid waste management system. Generally, landfill is considered as the land used for the final disposal of waste. A definition, published by International Solid Waste Association (ISWA) in 1992, viewed the concept to be – *the engineered deposit of waste onto and into land in such a way that pollution or harm to the environmental is prevented and, through restoration, land provided which may be used for another purpose* (Fauziah, 2010).

Compared with incineration, the costs of landfill construction and requirements of maintenance are much cheaper (Shekda, 2009). Many developing countries, like Malaysia, still keep landfill as a main MSW disposal method (APO, 2007). However, environmental impacts caused by landfills are getting serious in some areas that are lack of proper planning and management. The authorities need to make more efforts to prevent environmental pollutions. Stricter regulations and effective operation and management can help landfills operators to decrease these environmental impacts.

Selection of suitable landfill sites plays a key role in proper landfill plan and effective management (Pearce *et al.*, 2005; Fauziah, 2010). A proper site will help to decrease the burden of resources (San and Onay, 2001). Many of factors need to be considered with a multiple criteria system approach when making the decision on adjusting a suitable landfill site (Fauziah, 2010). The level of water table and the maximum waste depth are two main factors considered while making such decision. Generally, a site with a very low water table and over 100 meter depth available for waste deposition would be more cost-effective for land-use (Fauziah, 2010).

Eiselt (2007) proved that at least four main standards are required in the principles of effective landfill management:



1. Nuisances such as odors, fires, insects, birds, windblown litter and visual intrusion should be kept at a minimum
2. Good compaction of the waste should be ensured
3. Problems of water pollution and gas generation should be minimized
4. The management of the site should reflect the after-use for which the reclaimed land is intended.

Due to the application of different technologies, landfills are classified into four main types:

- a) Open dumps
- b) Controlled-dumps
- c) Sanitary landfill, and
- d) Secure landfill

Each type of landfill has its own advantages and drawbacks. Comparisons among these four classes are indicated in Table 2.2. Normally, these differences are based on cost, environmental impacts and socio-economic aspects. To start up an effective landfill, many aspects need to be considered such as suitable site, good design and construction, proper monitoring and management during operation and post-closure periods (Eiselt, 2007; Fauziah, 2010).

Table 2.2 Advantages and Disadvantages of Different Types of Landfill

Type	Advantages	Disadvantages
Open Dump	<ul style="list-style-type: none"> <li>• Easy access</li> <li>• Extended lifetime</li> <li>• Low initial cost</li> <li>• Aerobic decomposition</li> <li>• Access to scavengers</li> <li>• Material recovery high</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental contamination</li> <li>• Overuse, many noxious sites</li> <li>• Unsightly, need remediation</li> <li>• Ground and surface water contamination</li> <li>• Encouraged vermin, pest and vectors to diseases</li> <li>• Indiscriminate use</li> <li>• Least efficient</li> </ul>
Controlled Dump	<ul style="list-style-type: none"> <li>• Less risk of environmental contamination</li> <li>• Allow long-term planning</li> <li>• Low initial cost</li> <li>• Easier rainfall runoff, reduced risk</li> <li>• Moderate cost for maintenance</li> <li>• Extended lifetime due to compaction</li> <li>• Controlled access and use</li> <li>• Material recovery lower</li> </ul>	<ul style="list-style-type: none"> <li>• Less accessible</li> <li>• Moderate environmental contamination</li> <li>• Decomposition slower</li> <li>• Higher cost of compaction</li> <li>• Higher cost for leachate and gas management</li> </ul>
Sanitary Landfill	<ul style="list-style-type: none"> <li>• Minimized environmental risk</li> <li>• Permit long-term planning</li> <li>• Reduce risk from leachate and gas contamination</li> <li>• Vector control</li> <li>• Extended lifetime due to compaction</li> <li>• Secure access with gate records</li> <li>• Eliminate risk to scavengers</li> <li>• Possible to harvest biogas</li> </ul>	<ul style="list-style-type: none"> <li>• Access requires longer siting process</li> <li>• High cost for construction</li> <li>• Slower decomposition of waste</li> <li>• High cost for leachate and gas management</li> <li>• No further material recovery activity</li> </ul>
Secure Landfill	<ul style="list-style-type: none"> <li>• Very minimal environmental risks</li> <li>• Allows long-term planning with accurate information</li> <li>• Prevent risk at site due to precautionary actions taken</li> <li>• Eliminate risk to scavengers</li> <li>• Prevent hazardous waste from contamination the environment</li> <li>• Pre-treated waste stop risk to environment i.e. no leachate etc.</li> </ul>	<ul style="list-style-type: none"> <li>• High construction cost</li> <li>• Minimum or almost absent of natural decomposition</li> <li>• High waste pre-treatment cost</li> <li>• High cost for maintenance</li> <li>• No further material recovery activity</li> </ul>

(Source: Fauziah, 2010)

Researchers indicate that a typical model of waste stabilization consists of five phases which are sequential and distinct (Pohland *et al.*, 1986). The characteristics of generated leachate and biogas and rate of their production from different phases are discriminatory. The phases are characterized of waste degradation as described in Figure 2.3.

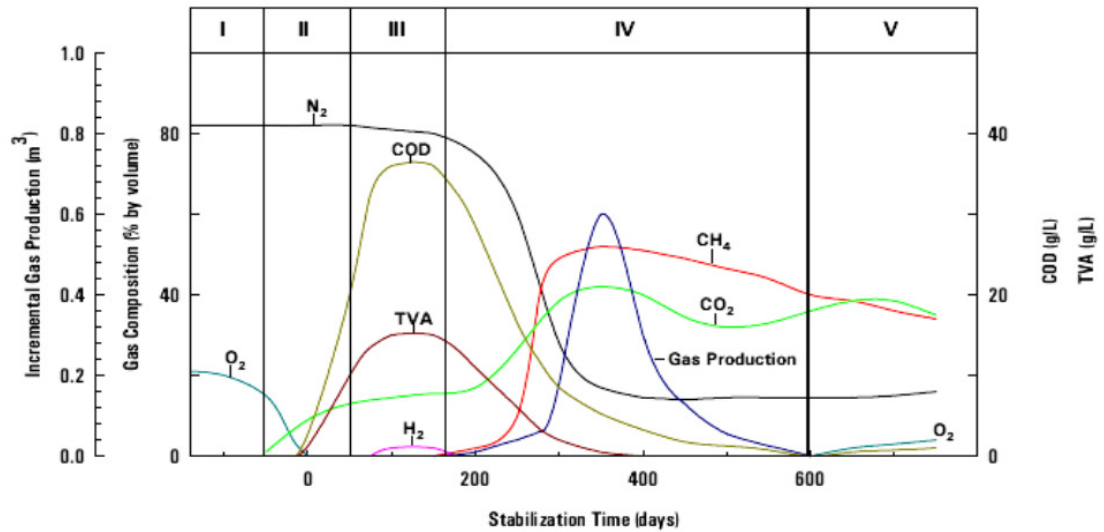


Figure 2.3 Phases of MSW Degradation in a Typical Landfill

(Source: Pohland *et al.*, 1986)

According to Pohland and Harper's research (1986), these five phases are described as:

Phase I: *Initial adjustment phase* - This phase occurs at the first placement of solid waste in the landfill and is characterized by moisture accumulation. Within a period called *initial lag time*, it ensures an adequate moisture level to enhance the availability of an active microbial community. This provides a compatible condition for the biochemical decomposition and preliminary changes that occur in the landfill.

Phase II: *Transition phase* - In the second phase, the capacity of landfill is exceeded sometimes due to the oxygen depletion that occur within in the landfill, hence encourage the transformation process between aerobic and anaerobic conditions. It is found that the electron acceptors from oxygen are shifted to nitrates and sulphates, and carbon dioxide is produced. At the phase measurable matters of volatile organic acids (VOA) and chemical oxygen demand (COD) in the generated leachate can be examined.

Phase III: *Acid formation phase* – At phase III which is after the consecutive solubilisation of solid waste, a higher concentration of intermediate VOAs occurred. It is due to the presence of biodegradable organic materials that encourage conversion by microorganisms. The value of pH decreases and the metal species begin to mobilize. Acidogenic bacteria accelerate the growth of viable biomass, and also increase the rate of substrate and nutrients consumption.

Phase IV: *Methane fermentation phase* – In this phase, methanogenic bacteria consume the intermediate acids produced in the last phase and generate carbon dioxide and methane. Nitrate and sulphate are oxidized to ammonia and sulphides, respectively. Though the value of pH grows slightly, it is controlled by the buffering of carbonate. Besides that, the methanogenic bacteria can continue to accumulate. The precipitation and complexation that take place at this phase also help to remove heavy metals in landfill.

Phase V: *Maturation phase* –This last phase is characterized of limited of substratum which slows down the rate of biological reaction in the landfill. Less biogas is generated

from this phase. In addition, the leachate generation is kept at a lower concentration level. The resistant organic material in landfill may degrade slowly.

### **2.8.1 Open Dumps**

Open dump is the cheapest and simplest option of solid waste disposal. At open dump sites, there is no controlling or monitoring system of leachate and biogas generated. It is easy to cause environmental impacts and problems to public health. In ancient decades, the open dump site was normally chosen in some abandoned or remote area, such as marshland or canyon. Increased waste generation brought by industrial blooming had reduced the rate of natural decomposing. In addition, the surrounding areas were seriously polluted by harmful components generated from open dumps. A better controlled waste disposal option is required to take the place of open dumps. USEPA (2000) reported that some advanced countries, such as America, have already forbidden disposing waste into open dumping site since early 1970s (Fauziah, 2010).

Normally, open dumps can be easily recognized by several characteristics. These include frowzy site place, without proper monitoring or controlling of waste, waste without daily cover or final cover, without proper leachate collection and landfill gas management, and strong odor. It is evident that open dump site is very cheap since it doesn't require high technology equipment and professional experts to operate the site. The cost of maintenance is minimal within all waste disposal options as well. Therefore, open dumps are the common choice of waste disposal in developing and under-developed nations (Issam *et al.*, 2010).

The impacts caused by open dumps potentially threaten natural environment and public health. Tons of highly deleterious components are discharged from open dump sites, such as heavy metals, polychlorinated biphenyl (PCB), PAHs and Volatile Organic Carbon (VOC) (Fauziah, 2010). From socio-economic aspect, the land value would decrease significantly, and the comfort of neighbouring residents will be seriously affected by release of toxic effluvia from open dump areas (Fauziah, 2010). With the rapid industrial development, these impacts are being critical in Malaysia; hence the introduction of Malaysian Action Plan 1988 which the authorities use to enforce the development of controlled dump site instead of open dumps (Latifah *et al.*, 2009; Zulkifli, 1993).

### **2.8.2 Controlled Dumps**

In developing countries, the first step to upgrade landfills is to establish controlled dumps which replace open dumps (The World Bank, 1999). Though the controlled dumps are non-engineered waste disposal site, yet choosing the site, operation, supervision and management systems are improved when compared with open dumps (UNEP, 2005). There are some basic requirements about facilities and technologies. Normally, controlled disposal sites emanate from reconstructing existing open dumps or use of fresh land.

Before choosing sites for controlled dumps, the hydro-geology of the intended area needs to be considered. UNEP (2005) reports that if pollution of groundwater in an open dump site is non-critical, then such an area is not recommended for conversion into a controlled dump site. Since the operating and monitoring system is enhanced in

controlled dumps technology, the environmental risks can be reduced drastically. Proper management strategy and system is crucial, otherwise, the controlled dump sites will degrade into a disordered open dumping site (Fauziah, 2010).

The life span of a controlled dump site can be estimated by the formula as follows:

$$LS = \frac{1}{365} \left\{ \left[ A \times d \times 1.33 \times 0.85 \right] + \left[ (WGR \times P) + \rho \right] \right\}$$

where is:

LS = estimated life span of the controlled dumpsite (years)

A = area of the disposal site (m<sup>2</sup>)

d = average depth of the disposal site (m)

WGR = waste generation rate (kg/person/day)

ρ = loose density of the waste (kg/m<sup>3</sup>)

P = population to be served (persons)

Note:

1) A waste generation rate of 0.5 kg/person/day may be used for developing countries (Shekdar, 2009).

2) The 1.33 factor in the equation accounts for an assumed average compaction factor of 33% achieved during landfill operations. For controlled dumpsites, it will be lower or nil.

3) The 0.85 factor in the equation accounts for a soil cover to waste ratio of 1:6 (for a given volume, 15% is soil cover and 85% is waste)

4) A loose un-compacted density of about 330 kg/m<sup>3</sup> is used to convert kg/day to m<sup>3</sup>/day (The World Bank, 1999). It may vary in some areas.

The estimate does not include land area for leachate treatment facilities, buffer zone and other auxiliary facilities.

Though controlled dumps need more financial support compared to open dumps, the environmental impacts are drastically reduced. Therefore, most middle income and low income nations prefer to update open dumps site to controlled dumps to reduce the environmental impacts. Installing leachate drainage and landfill gas vent are two main aspects when updating an open dump site to controlled disposal site (UNEP 2005). Though there are some basic requirements and investment on leachate and gas controlling facilities, the costs would be much lower compared with constructing a sanitary disposal landfill.

With the development of urbanization, the solid waste management system is required to be more effective and more integrated. The environmental threats from open dumps and even controlled dumps have become apparent. Hence, a better disposal option is required, which should be cost-effective in long term and low or nil environmental contamination. Therefore, sanitary landfills become a basic option for waste disposal in an effective IWMS.

### **2.8.3 Sanitary Landfill: A Systematic Approach to Solid Waste Disposal**

There are several definitions of sanitary landfill and the most common definition is according to USEPA. Sanitary landfill is considered as “an engineered method of disposing of solid waste on land in a manner that protects the environment, by spreading



the waste in thin layers, compacting it to the smallest practical volume and covering it with compacted soil by the end of each working day or at more frequent intervals if necessary". A sanitary landfill is used for disposing perdurable waste and depositing non-hazardous waste over six months. According to USEPA, three main types of waste are allowed for disposal of sanitary landfill facilities (Table 2.3).

Table 2.3: USEPA Classification of Sanitary Landfill

Class	Waste type permitted
I	All non-hazardous solid waste: - Municipal solid waste, bulky waste, construction and demolition waste, vegetative waste, dry industry waste, animal and food processing waste and abestos containing waste.
II	Specific category of non-hazardous waste: - Dry industrial wastes, construction and demolition waste, vegetative waste, and asbestos containing waste
III	Inert non-putrescible and non-hazardous waste: - Bulky waste and vegetative waste

(Source: Fauziah, 2010)

A typical sanitary landfill is composed of a base liner, daily cover liner, leachate collection and monitoring system; landfill gas monitoring facilities and other pollution treatment processes. These parts make sanitary landfill work environmentally. Lining system is one of the key elements in sanitary landfill construction. Normally, the place with a natural existing layer is considered a preferred construction site. Researches indicate that clay can be a good option because the permeability factor is low (Fauziah, 2010). Figure 2.4 shows the structure of typical sanitary landfill.

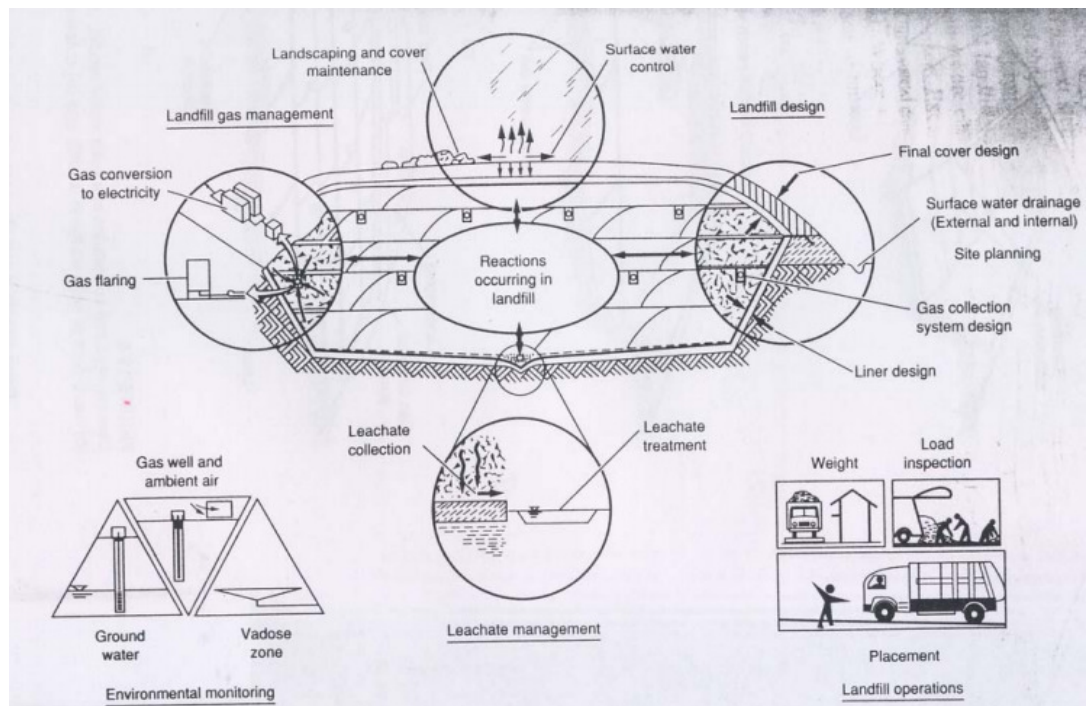


Figure 2.4 Landfill Operations and Processes

(Source: Tchobanoglous *et al.*, 1993)

Basically, two main types of sanitary landfills are classified based on the landfill operations. One is Area Method and the other is Trench Method (UNEP, 2005). Some other methods are normally based on modifications or combinations of both. From the technical part, the sanitary landfills have three main types: aerobic, anaerobic and semi-aerobic. One of advantages of aerobic landfill is that organic loading in the leachate is moderate. Therefore, the requirements for leachate treatment facilities can be reduced. The anaerobic landfill is normally used for waste digestion but semi-aerobic landfill is often preferred and more effective because it can absorb more air that accelerates the rate of decomposition (UNEP, 2005).

Comparisons among open dumps, controlled dumps and sanitary landfills have been done by UNEP (2005) as shown in Table 3.3. It is based on differences of technology and operation implementation. When it comes to engineering aspects, sanitary landfill system is well-designed and controlled, which can effectively minimize environmental impacts. It is indicated that sanitary landfill disposal and treatment system is the most cost-effective option in developing nations (Sandra, 1996). Setting up of more sanitary landfills has been suggested for urban waste disposal, through in reference to the financial aspect, the waste composting system normally costs 2-3 times more than that of sanitary landfill (Sandra, 1996). The incineration of solid waste is considered one of the highest investments of solid waste disposal, which costs 5-10 times higher than constructing a sanitary landfill (Sandra, 1996).

However, though the cost of sanitary landfill is less than some other high technologies of waste management, it still has high technological requirements for equipment and professional operation. Middle-income and low-income regions still prefer to non-sanitary landfills based on financial involvement. Take Malaysia for example, based on the data from MHLG (2010), there is just 8 sanitary landfills out of 176 registered landfills. The similar situation is observed in India and China as well.

While constructing a sanitary landfill, the main purpose is to avoid any environmental impacts. In fact, not all the sanitary landfills are under good operation and management. One fast way to mitigate this increasing tension of waste disposal is to improve the efficiency of existing sanitary landfill system.

Table 2.4 A Summary of the General Characteristics of Waste Disposal Facilities

Criteria	Open dump	Controlled Dump	Sanitary landfill
Siting of facility	<ul style="list-style-type: none"> <li>·Unplanned and often improperly sited</li> </ul>	<ul style="list-style-type: none"> <li>·Hydro-geologic conditions considered</li> </ul>	<ul style="list-style-type: none"> <li>·Site chosen is based on environmental, community and cost factors</li> </ul>
Capacity	<ul style="list-style-type: none"> <li>·Site capacity is not known</li> </ul>	<ul style="list-style-type: none"> <li>·Planned capacity</li> </ul>	<ul style="list-style-type: none"> <li>·Planned capacity</li> </ul>
Cell planning	<ul style="list-style-type: none"> <li>·There is no cell planning</li> <li>·The waste is indiscriminately dumped</li> <li>·The working face/area is not controlled</li> </ul>	<ul style="list-style-type: none"> <li>·There is no cell planning, but the working face/area is minimized</li> <li>·Disposal is only at designated areas</li> </ul>	<ul style="list-style-type: none"> <li>·Designed cell by cell development</li> <li>·The working face/area is confined to the smallest area practical</li> <li>·Disposal is only at designated cells</li> </ul>
Site preparation	<ul style="list-style-type: none"> <li>·Little or no site preparation</li> </ul>	<ul style="list-style-type: none"> <li>·Grading of the bottom of the disposal site</li> <li>·Drainage and surface water control along periphery of the site</li> </ul>	<ul style="list-style-type: none"> <li>·Extensive site preparation</li> </ul>
Leachate Management	<ul style="list-style-type: none"> <li>·No leachate management</li> </ul>	<ul style="list-style-type: none"> <li>·Partial leachate management</li> </ul>	<ul style="list-style-type: none"> <li>·Full leachate management</li> </ul>
Gas management	<ul style="list-style-type: none"> <li>·No gas management</li> </ul>	<ul style="list-style-type: none"> <li>·Partial or no gas management</li> </ul>	<ul style="list-style-type: none"> <li>·Full gas management</li> </ul>
Application of soil cover	<ul style="list-style-type: none"> <li>·Occasional or no covering of waste</li> </ul>	<ul style="list-style-type: none"> <li>·Covering of waste implemented regularly but not necessarily daily</li> </ul>	<ul style="list-style-type: none"> <li>·Daily, intermediate and final soil cover applied</li> </ul>
Compaction of waste	<ul style="list-style-type: none"> <li>·No compaction of waste</li> </ul>	<ul style="list-style-type: none"> <li>·Compaction in some cases</li> </ul>	<ul style="list-style-type: none"> <li>·Waste compaction</li> </ul>
Access road maintenance	<ul style="list-style-type: none"> <li>·No proper maintenance of access road</li> </ul>	<ul style="list-style-type: none"> <li>·Limited maintenance of access road</li> </ul>	<ul style="list-style-type: none"> <li>·Full development and maintenance of access road</li> </ul>

Table 2.4 A Summary of the General Characteristics of Waste Disposal Facilities

(Con't)

Fencing	·No fence	·With fencing	·Secure fencing with gate
Waste inputs	·No control over quantity and/or composition of incoming waste	·Partial or no control of waste quantity, but waste accepted for disposal is limited to MSW	·Full control over quantity and composition of incoming waste ·Special provisions for special types of wastes
Record keeping	·No record keeping	·Basic record keeping	·Complete record of waste volumes, types, source and site activities/events
Waste picking	·Waste picking by scavengers	·Controlled waste picking and trading	·No on site waste picking and trading
Closure	·No proper closure of site after cease of operations	·Closure activities limited to covering with loose or partially compacted soil and replanting of vegetation	·Full closure and post-closure management
Cost	·Low initial cost, high long term cost	·Low to moderate initial cost, high long term cost	·Increased initial, operational and maintenance costs, moderate long term cost
Environmental and health impacts	·High potential for fires and adverse environmental and health impacts	·Less risk of adverse environmental and health impacts compared to open dump site	·Minimum risk of adverse environmental and health impacts

(Source: UNEP, 2005)

#### **2.8.4 Environmental and Health Impact of Landfills**

A potential linkage between landfill, harmful environment and health outcomes is of concern and should be monitored continuously especially when sited near residential area. The concerns are mainly focused on gas emission and leachate drainage (Hassan, 2000; Fauziah, 2010). An appropriate monitoring and management system should be conducted to inspect the pollution level. Environmental contamination is not the only aspect affected by landfill sites. The health impacts are always reported because of inappropriate landfills construction and management.

At an Indian landfill, it was reported that the workers in the disposal site suffered of serious health problems, which includes respiratory disease, inflammation and lung weakening (Fauziah, 2010). San and Onay (2001) reported that leachate pollution can cause damages to born marrow and DNA of mammals. These damages may even be hereditary to next generation. An ammonia concentration has been proven to affect the toxicity level of leachate generated (Fauziah, 2010). There are five main parameters of the environmental indexes in landfill inspection listed in Table 2.5. They can help to determine the intensity of contamination from landfill emission.

Table 2.5 Variables Affecting the Five Elements of Environmental-Landfill Indexes

Parameters	Variables
All elements	Compaction, waste and organic matter types Age, cover material Control of leachate Operationality Final cover
Surface water	Inclination to the surface beds Permeability of surrounding strata Surface water in the surroundings Surface drainage systems, rainfall Landfill lining system Release point location in surface run Release point location in floodwater storage volume
Ground water	Aquifer characteristics Surface drainage system, rainfall Landfill lining system Fault Release-point location in surface run Release-point location in floodwater storage volume
Atmosphere	Rainfall, gas control, paths
Soil	Waste slope, gas control, landfill lining system Release-point location in surface run Release-point location in floodwater storage volume
Health	Gas control, environmental control Distance to population, distance to infrastructure Available equipment

(Source: Fauziah, 2010)

According to various investigations, the development of landfills has the trend to be large scale and long-term life span to meet the needs of increasing waste. Hazardous waste and liquid chemical has been deposited to landfills. It is necessary to construct a

better design structure, monitoring and management system that will enhance the environmental controls and public health protection.

## 2.9 Economic Evaluation

### 2.9.1 The Concept of Economic Values

A basic precondition is required for the projects economic evaluation of its environmental impacts (Bolt *et al.*, 2005). The various goods and services produced by ecosystem are valued by human according to their contributions to human society (Bolt *et al.*, 2005). The extension of these contributions from goods and services is defined as *economic values* produced by the environment (Bolt *et al.*, 2005) (Figure 2.5).

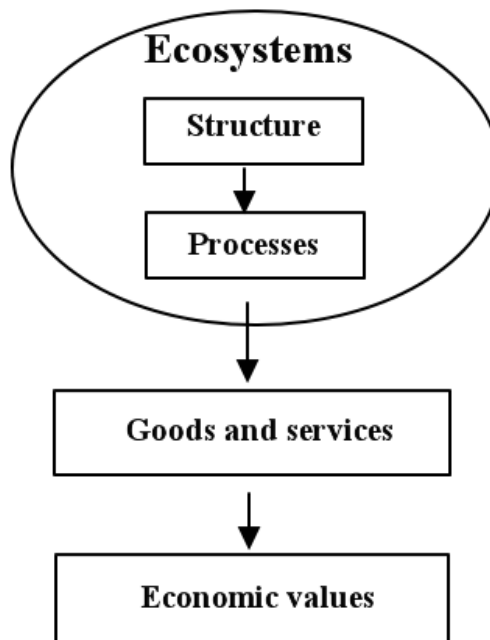


Figure 2.5 The Flow Chat from Ecosystems to Economic Values

(Source: Bolt *et al.*, 2005)



Changes in this flow can affect the nature and extent of the *economic values*. Positive changes will raise the economic values of these environmental goods and services, which can be classified as environmental benefits (EFTEC, 2005). By contrast, the negative changes cause reduction to economic value and it is considered as environmental costs. Such changes in this economic value flow can be caused by either nature events or human activities (EFTEC, 2005). The changes triggered by nature are unpredictable. However, the influences by human projects can be identified and quantified in the flow of goods and services produced by the environment with conversion into benefits or cost (EFTEC, 2005).

The total economic value (TEV) theory is now commonly recommended as an adequate framework to analyse the economic evaluation of environmental impacts. Figure 2.6 illustrates the total economic value and other components consisting of the whole framework. Every component has different usages within the ecosystem.

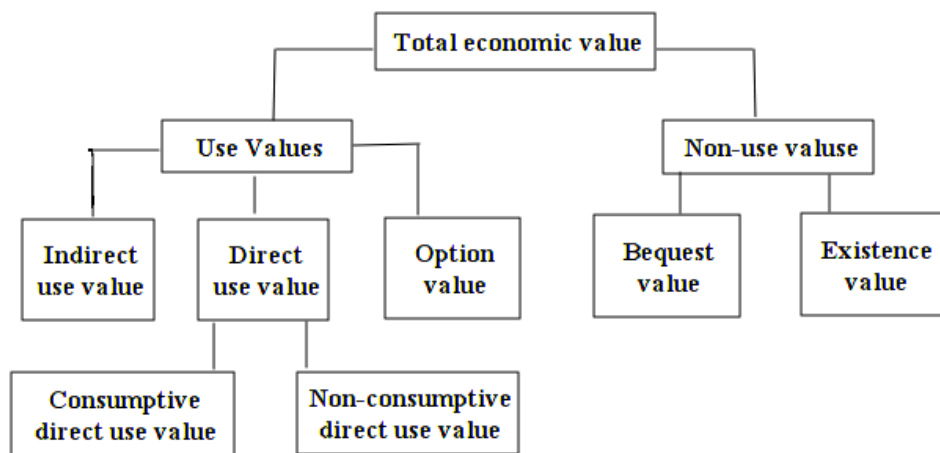


Figure 2.6 Total Economic Value and Its Components

(Source: Pearce *et al.*, 2000)

### **2.9.2 The Economic Evaluation of Environmental Projects**

Economic methods have been implemented in research areas of environmental policy decision – making, sustainability development and relative environment projects management (Thomas and Callan, 2007). These evaluation techniques have been applied in Europe, America and Japan (Theng *et al.*, 2005). The Malaysian authorities started to be more concern about the linkage between nature and economic development (Theng *et al.*, 2005). Higher environmental requirements need to be considered in policy decision-making and projects assessment to preserve the nature conservation (Haynes, 1995).

Waste minimization and pollution controls require considerable expenditures from the government budgets or private investments. Estimation of the economic value can be useful evaluation tool for these environment-related activities. It can help to determine whether converting natural resources to goods and services leads to more opulent society or shortening the human generations. The economical conceptions applied in environmental projects can explain proposed policies and approaches logically (Srivastava *et al.*, 2003).

A research by Maritza (2010) applies the cost-benefit analysis model in decision making in Belize. The cost-benefit analysis is to assess the construction and operation of semi-aerobic landfills in comparison with open-dump sites (Maritza, 2010). It is found that semi-aerobic landfill can give profit of USD 143 million in total and USD 12 million on

health benefit. Open dumps lands can generate USD 12 million through steps by steps restoring or converting into semi-aerobic sanitary landfill step by step.

A workshop held by Srivastava *et al.* (2003) develops a flexible computer model for economic evaluation of MSW management. This economic model can calculate the capital to build a new landfill for any city in India. Based on inputs such as population and amount of waste generation, the model is able to estimate the construction cost, the operating costs within the life span of the landfill and post-closure cost. This information can help the decision-maker to make economical and environmentally viable options in building a new disposal site.