CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 General Description

It is an important goal to organise and implement an integrated waste management system (IWMS) for developing countries. IWMS can help these industrialising regions to achieve sustainable development in the future. Various types of MSW treatment and disposal options are able to form the IWMS and improve the efficiency of IWMS. It is known that effective IWMS can protect the natural environment and public health by efficient waste collection, waste treatment, recycling and final disposition to design and implement an IWMS.

Many factors such as financial, technical support, and environmental impacts, are to be carefully considered before the implementation of any waste management activities. Evaluating the efficiency is a key tool to help improve the existing waste management activities. Therefore, in this research a widely recommended landfill model (Landfill A) and a selected landfill site (Landfill B) to analyse the efficiency of different waste disposal options in Malaysia. The objective is to compare the economical efficiency between a recommended sanitary landfill (Landfill A) and an existing operational landfill in Malaysia (Landfill B).

This research is conducted according to the instructions and valuations of Fukuoka Method (FM) landfill system considerations which are analysed in Chapter 3. The national data is mainly gathered from interviews and survey of literatures.

5.2 Economic Evaluation of FM Landfill – A Case Study in Malaysia

Proper designs of leachate and gas collection system are necessary for rapid emissions removal. The FM semi-aerobic landfill is currently constructed in many developing nations for different purpose. It includes developing new sanitary landfill and upgrading the existing open-dumps to a proper waste disposal landfill. There are three main concepts of FM in developing countries, and they are

a) Low cost: For example, the Tafaigata landfill located in the central region of Upolu Island in Samoa just cost RM 1,400,000.
b) The maintenance is simple and easy. It can minimize energy consumption. As for raw materials, FM landfill utilizes natural cleansing material which comprised of available reusable waste in the landfill.
c) Sustainability

The advantages of FM landfill are listed as follows:

i. The structure of Fukuoka landfill is simple and low cost to construct.

It is available for using local materials during construction, like bamboo, waste drums and waste tires.

ii. In Fukuoka landfill, the speed of decomposition is rapid and sanitary.

It generates fewer odours compared to other types of landfills. The overall layer is quite smooth, which is easier for land use after closure.

iii. The leachate treatment system is easy to construct and manage.

Since the leachate can be removed upon it generating, facilities are clean and maintains easily. One of the most important aspect of FM landfill is it allows the conversation existing dumpsites to sanitary landfills.

The case study on FM landfill – Landfill A is designed to service an area with the population of 500,000 people. The projection of waste generation shows in Table 5.1.

Based on the projection, the total amount of solid waste disposed to Landfill B in 20 years are around 1.5 million tonnes. If the density of waste is 700 kg/m^3, the volume requirement of Landfill A is:

$3,471,137 \times 1000\ kg / (700\ kg/m^3) \approx 5.0$ million m^3

Table 5.1 Projection of Total Waste Disposed at Landfill A

Year	Population	Waste generation amount (tonnes/year)	Waste disposing to Landfill (%)	Total waste amount disposed to Landfill A (tonnes/year)
2001	500,000	160,600	97.0	155,782
2002	512,500	164,615	96.0	158,030
2003	525,313	168,730	95.0	160,294
2004	538,445	172,949	94.0	162,572
2005	551,906	177,272	93.0	164,863
2006	565,704	181,704	92.0	167,168
2007	579,847	186,247	90.8	169,112
2008	594,343	190,903	89.1	170,095
2009	609,201	195,676	88.1	172,390
2010	624,431	200,567	86.8	174,092
2011	640,042	205,582	85.3	175,361
2012	656,043	210,721	84.1	177,216
2013	672,444	215,989	82.8	178,839
2014	689,256	221,389	81.3	179,989
2015	706,487	226,924	80.1	181,766
2016	724,149	232,597	78.8	183,286
2017	742,253	238,412	77.1	183,815
2018	760,809	244,372	75.8	185,234
2019	779,829	250,481	74.1	185,607
2020	899,325	256,743	72.3	185,625
Total		4,102,472		3,471,137

It is assumed that the usage of cover may require 15% extra volume, so the actual volume is 5,702,582 m^3. The average depth of Landfill A is 15 m, therefore, the area of Landfill A is 380,172 m^2 (38 ha). Since 40% additional area for facilities is required, the total area of Landfill A is about 50ha.

Details of costs in Landfill A, including construction, operation and closure can be illustrated in Figure 5.1 – 5.3.

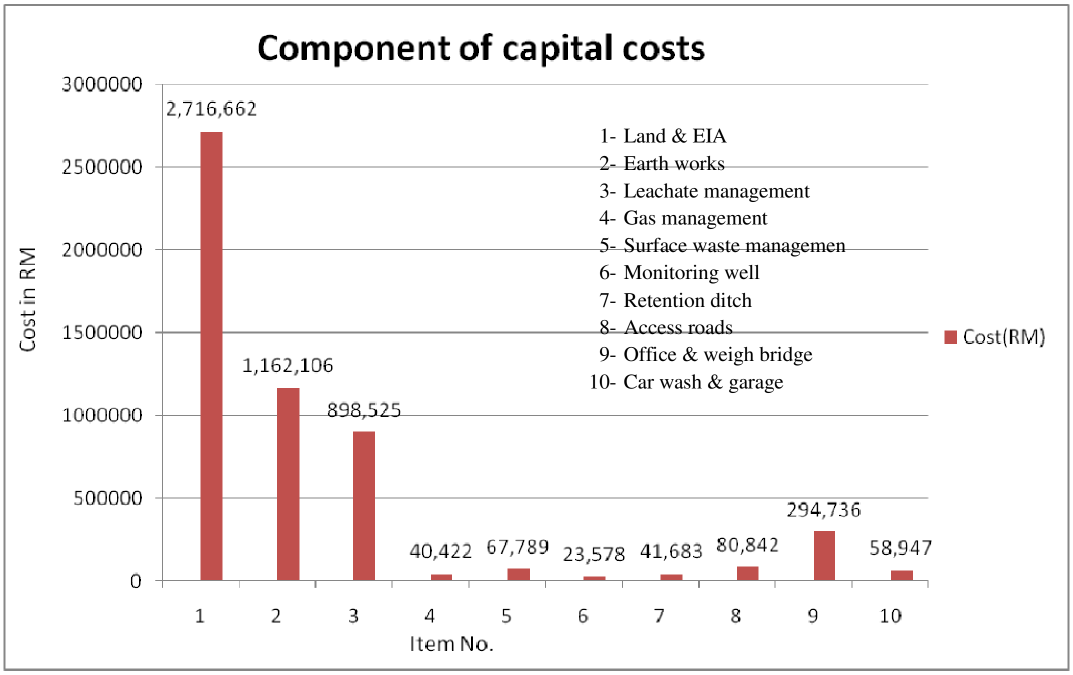

Figure 5.1 Components of Capital Costs in Landfill A

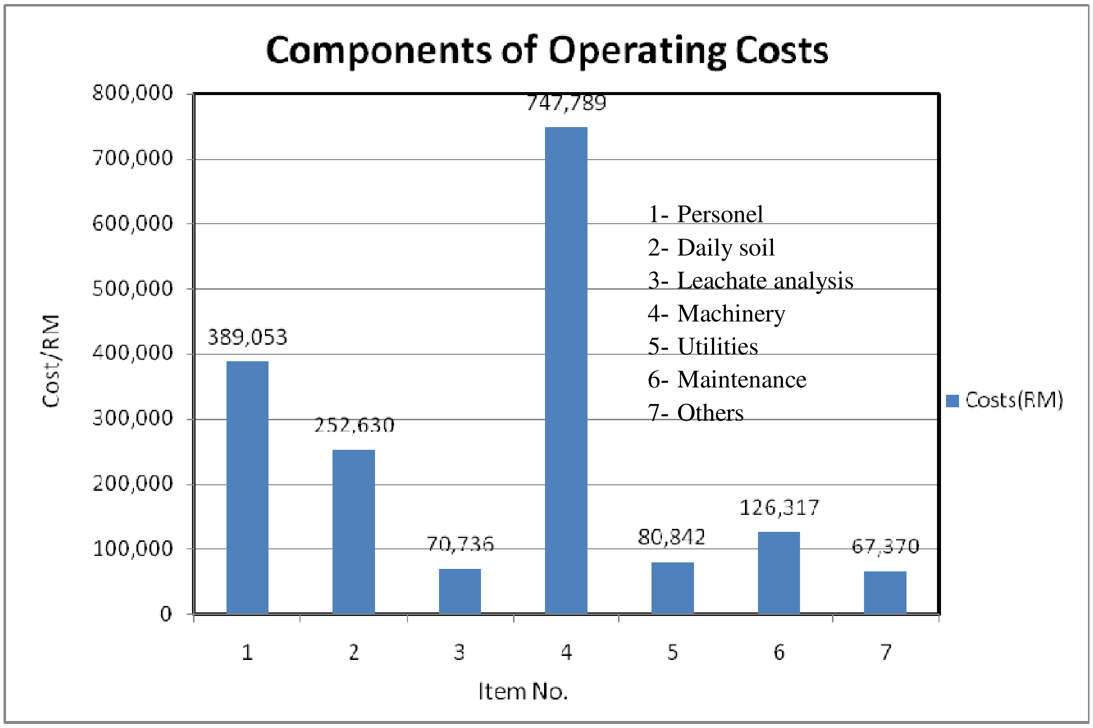

Figure 5.2 Components of Operating Costs in Landfill A

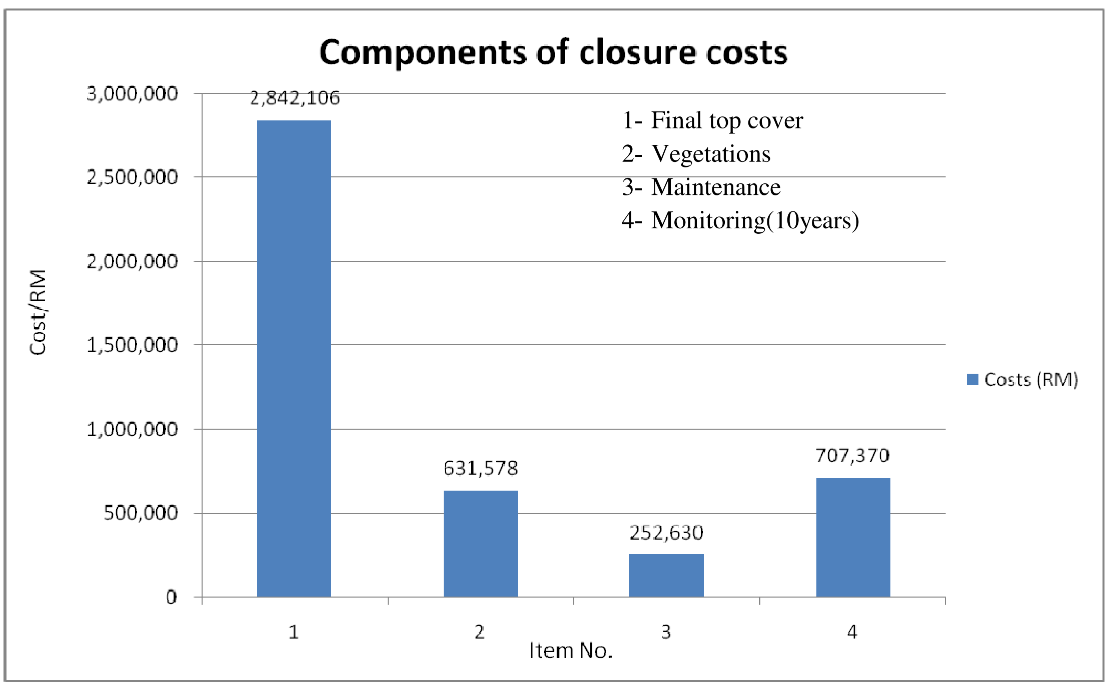

Figure 5.3 Components of Closure Costs in Landfill A

From the above figures, the capital cost is about RM 5.4 million, with land survey and formation contributed the largest percentage. The first year operating cost is estimated at RM 1.7 million. Final top cover is the most important part in the closure stages thus total costs of closure are estimated at RM 4.4 million.

The average tipping fees is RM 36 / tonne in Malaysia, and the annual MSW growth rate is around 3%. Landfill A has a recycling program and leachate circulation system which can create the environmental benefit around RM15, 000 monthly. Therefore, the costs and benefits of Landfill are calculated and shown in Table 5.2.

Table 5.2 Economical Cost and Benefit of Landfill A

Year	Costs (RM) (Construction + Operation)	Benefits (RM)
2001	5,840,026	5,608,152
2002	5,892,068	5,859,767
2003	5,981,407	5,943,696
2004	6,075,213	6,028,159
2005	5,728,506	6,113,131
2006	5,809,667	6,198,583
2007	5,894,886	6,270,675
2008	5,984,366	6,307,105
2009	6,078,320	6,392,226
2010	6,176,971	6,455,350
2011	6,280,555	6,502,389
2012	6,389,319	6,571,186
2013	6,503,520	6,631,351
2014	6,623,431	6,673,998
2015	6,749,338	6,739,876
2016	6,881,541	6,796,252
2017	7,020,353	6,815,873
2018	7,166,107	6,868,473
2019	7,319,147	6,882,291
2020	7,326,155	6,882,988

Figure 5.4 indicates the relationship between cost and benefit, in which the economical balance point Q can be estimated.

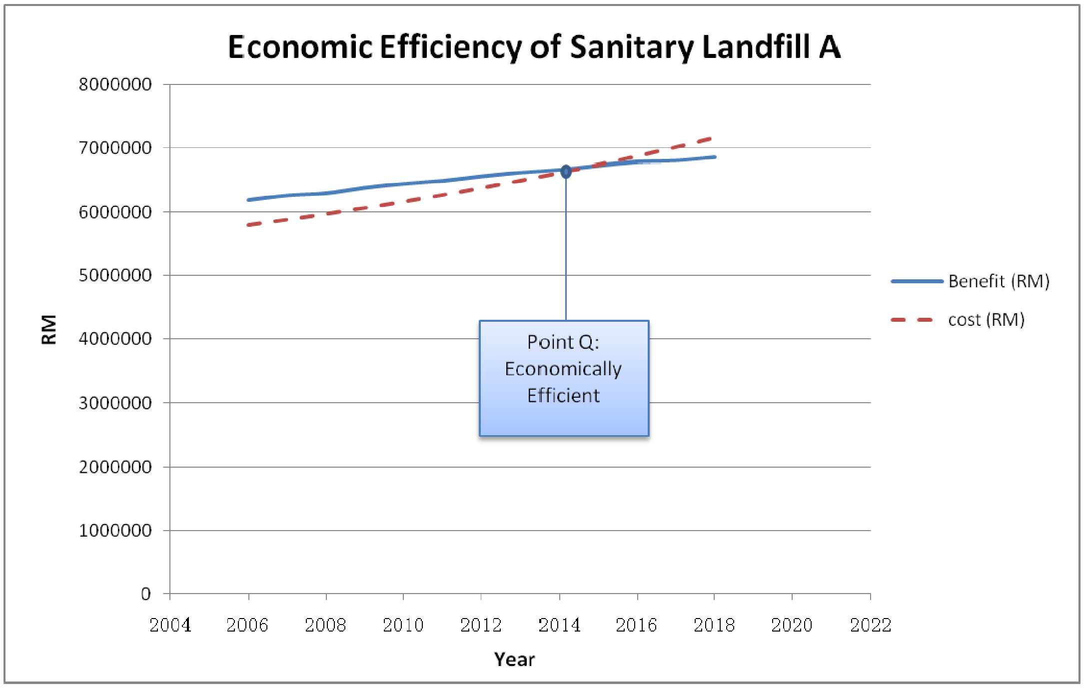

Figure 5.4 Economical Efficiency of Sanitary Landfill A

The above graph shows the economical balance will be reached after 15 operational years. Since Landfill A has low investment on basic construction, the capital cost can be recovered within a short period of time. However, the requirements of maintenance and professionals are specific and high. Therefore, the costs of operation, maintenance of facilities, and costs of training and management increases slightly in the long-term.

Since new approaches such as recycling and incineration, are slowly being introduced to MSW management system, the amount of waste to be disposed off to landfills will reduce. This will lead to the decrease of annual revenue at landfill sites due to reduction in income generated from tipping fees. Therefore, it is suggested that an integrated MSW system are to be constructed. This can joint various waste treatments and disposal methods effectively. Though Landfill A will achieve the economically efficient point by 2015, new green technologies like biogases power generation facilities are recommended to reduce both economic cost and environmental impacts.

5.3 Landfill B – A Selected Operational Sanitary Landfill in Malaysia

5.3.1 The General Information and Technology Investment of Landfill B

Landfill B mainly receives and treats the waste from western Klang Valley covering a population of approximately 0.6 million in 2007. This landfill started to operate the first cell officially in 2007, and the total landfill area is 160 acres. The design capacity of Landfill B is 1250 tonne per day. The lifespan of the landfill is approximately 25 year with active waste dumping of 16 year. However, the current factual capacity is 2000-3000 tonne/day during operational period. Therefore, the active waste dumping time has to be shortening to 8 years because of the waste overload. The overview of Landfill B is shown in Plate 5.1 and Plate 5.2.

Plate 5.1 The Overview of Landfill B (1)

Plate 5.2 The Overview of Landfill B (2)

In landfill B, the average depth of excavation is around 2.5m, and the lowest point of the landfill bottom liner is at an elevation of 0.5 m in general. All municipal solid waste, including residential, commercial, industrial (non-scheduled waste), governmental or institutional establishments, and community (markets, community centres) areas are accepted by this landfill. Gardens and bulky waste (white goods such as appliances, furniture) is also acceptable.

The recycling programmes has partaken partial pressure of waste disposal. It is claimed that the recycling rate can achieve around 1% in the beginning at the landfill site. This figure is assumed to increase at 0.1% annually. Another consideration of landfill design and operation is the composition of waste. Generally, the composition can be differed from climate, location, economic standards and local culture.

According to the waste generation rate in Selangor (1.4 t/cap/yr) and annual growth rate (1.7%) from 2001 to 2006, and the average recycling rate at the landfill site is estimated at 1.5 % as shown in Table 5.3.

Table 5.3 Estimation of Waste Disposal to Landfill B

Year	Population in the research area	Waste generation (tonnes/year)	Disposal methods (% by weight)		Total waste final disposed to the landfill (tonnes/year)
			Recycling	Final disposal	
2007	620,000	868,000	1.0	99.0	859,320
2008	630,540	882,756	1.1	98.9	873,046
2009	641,259	897,763	1.2	98.8	886,990
2010	652,161	913,025	1.3	98.7	901,155
2011	663,247	928,546	1.5	98.5	914,618
2012	674,523	944,332	1.6	98.4	929,222
2013	685,989	960,385	1.8	98.2	943,098
2014	697,651	976,712	2.0	98.0	957,177
Total		7,371,518			7,264,627

Note: the population growth rate is 1.7% per annum

Based on the data obtained, the total amount of municipal waste disposed may reach around 8 million tonnes under current operational situation after 8 years. It is assumed that the specific density of waste is about 700 kg/m^3. This is an average value for compacted landfill waste in developing nations. Therefore, the total volume of Landfill B can be roughly calculated as:

$7,873,918 * 1000kg / (700kg/m^3) = 11,248,454\ m^3$

Other details design information of Landfill B are calculated and listed as follows:

a) Leachate Treatment Plant

This plant is equipped with collection system from landfill cell. Sequential Batch Treatment (SBR) is used for biological treatment. It composes of 5 aerated lagoons and 2 retention ponds. Finally, the leachate will be treated at advance and polishing treatment facilities including mixing tank, dissolved air floatation unit, sand filter and activated carbon filter (Plate 5.3 and Plate 5.4). The average capacity of this leachate treatment plant is 450 m^3 per day. It is reported that 18 parameters to be complied as stated in the EIA. However, the current new regulation requires compliance to 29 parameters.

Plate 5.3: Leachate Treatment Plant

Plate 5.4 Leachate Retention Pond

b) Gas Treatment System

In Landfill B, methane gas produced from decomposition of waste will be extracted from the landfill through vertical gas well. There was no record about gas generation from 2007 till now. Current practice involves the methane gas being flared at the flaring unit. With the installation of green generator, the quantity and quality of the gases will be recorded for future power generation plan. It can contribute to reduce gas accumulation and odor problem.

c) Machineries Used at The Landfill B

Track type bulldozer – 5 units

Excavator – 4 units

Dump truck – 4 units

Landfill compactor – 2 units

The garbage truck will be directed to the tipping platform as directed by the traffic controller. Waste will be pushed and compacted in layers of 300mm to 500mm.

d) Soil Daily Cover

Soil cover is applied on a daily basis. It is mainly to control the surface run-off and run on, leachate generation, odor problem, uncontrolled gas migration, lateral leachate and others. Landfill B uses marine clay as the daily soil daily cover at 150 – 500 mm thickness (Plate 5.5).

Plate 5.5 Daily Cover

Alternative daily cover (ADC) namely PPW Woven Geo-textile as15, 000 – 50,000 sq.m cover materials were proposed to reduce odor problem, erosion, leachate generation, and aesthetic.

5.3.2 The Costs and Benefits Calculation of Landfill B

According to the interviews and literatures, the basic cost and benefit of Landfill B model covers various aspects. Among there are land value and economic value, respectively. A wider range is shown in Figure 5.5.

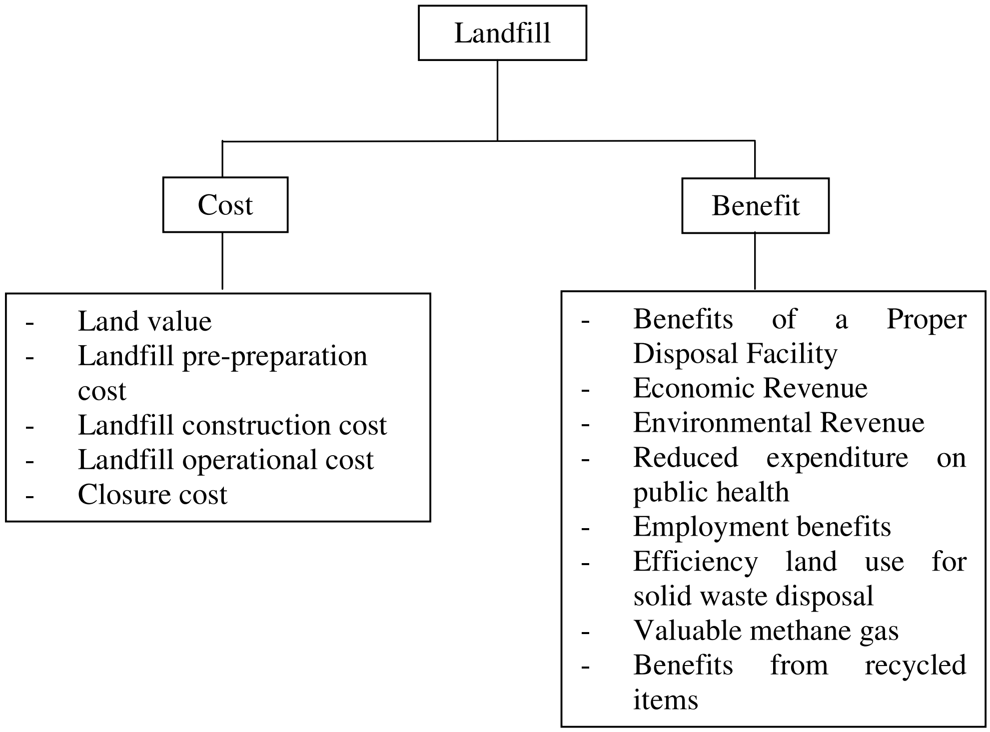

Figure 5.5 Examples of Costs and Benefits Considerations in Landfill

The costs of every phase need to be calculated or estimated separately. This can provide the details cost of landfill development, construction and management of entire landfill. Important aspects to be considered include:

a) Pre-preparation Phase

In this stage, detailed environmental impact assessment (DEIA) must be conducted and approved by Authorized department. Generally, costs in this phase should include site surveys, laboratory analysis, site formation, and construction of basement and others.

b) Construction Stage

It includes construction of facilities including foundation works (Plate 5.6). The costs involved are material costs, labour costs as well as other management expenses.

Plate 5.6: Construction Stage

c) Operational period

Under operation and maintenance stage, costs such as monitoring, daily coverage, facility maintenance, and administration are required to be considered (Plate 5.7).

Plate 5.7: Operation Period

d) Closure Stage

Normally, the costs for landfill closure can be estimated in several areas including: costs of final top cover soil, leachate and gas emission monitoring, and expenses of necessary facilities maintenance. These costs will continue for a period after landfill closure.

In economic terms, the multiplier effects of developing Landfill B are much higher than the cost of development calculated in this study. This is because any money pumped into the economy often generates a cycle of business that in turn spins other businesses directly and indirectly. The values gathered do not include escalation factors (interest rates), project financing and tax. The estimated costs including capital cost, operating cost and closure cost are in absolute values. It is shown in Figure 5.6 – Figure 5.8. The costs calculation and estimation are detailed in Appendix I, II, and III. The estimations generally based on information gathered from Landfill B, Local Authorities, and prices of raw materials and labor market in Malaysia.

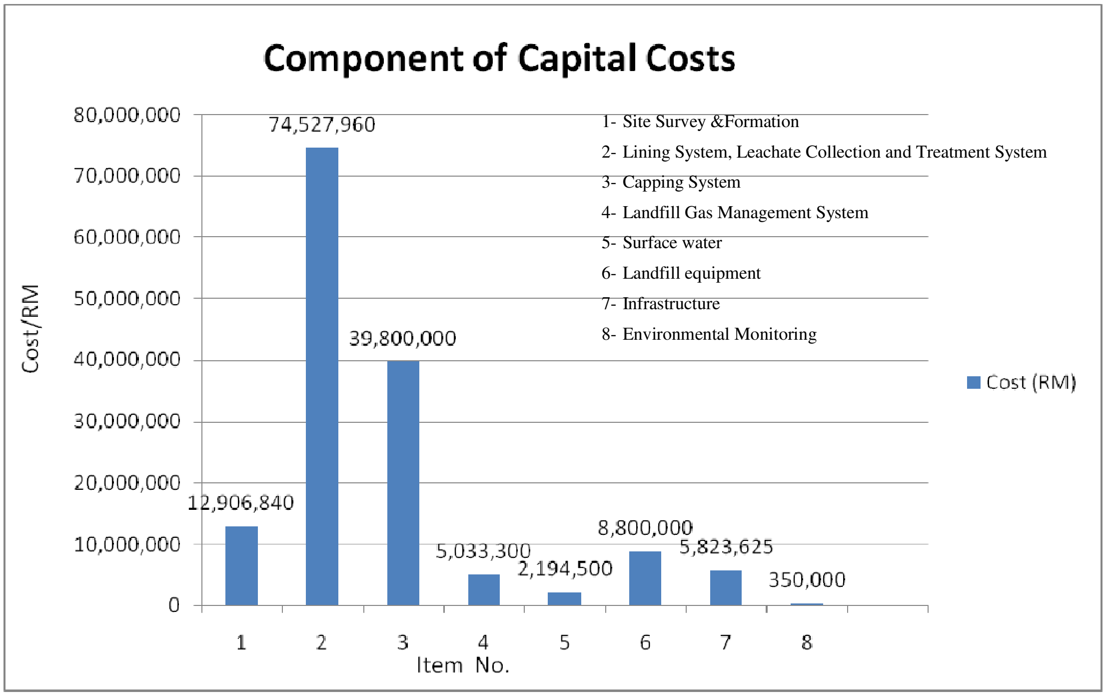

Figure 5.6 Components of Capital Costs in Landfill B

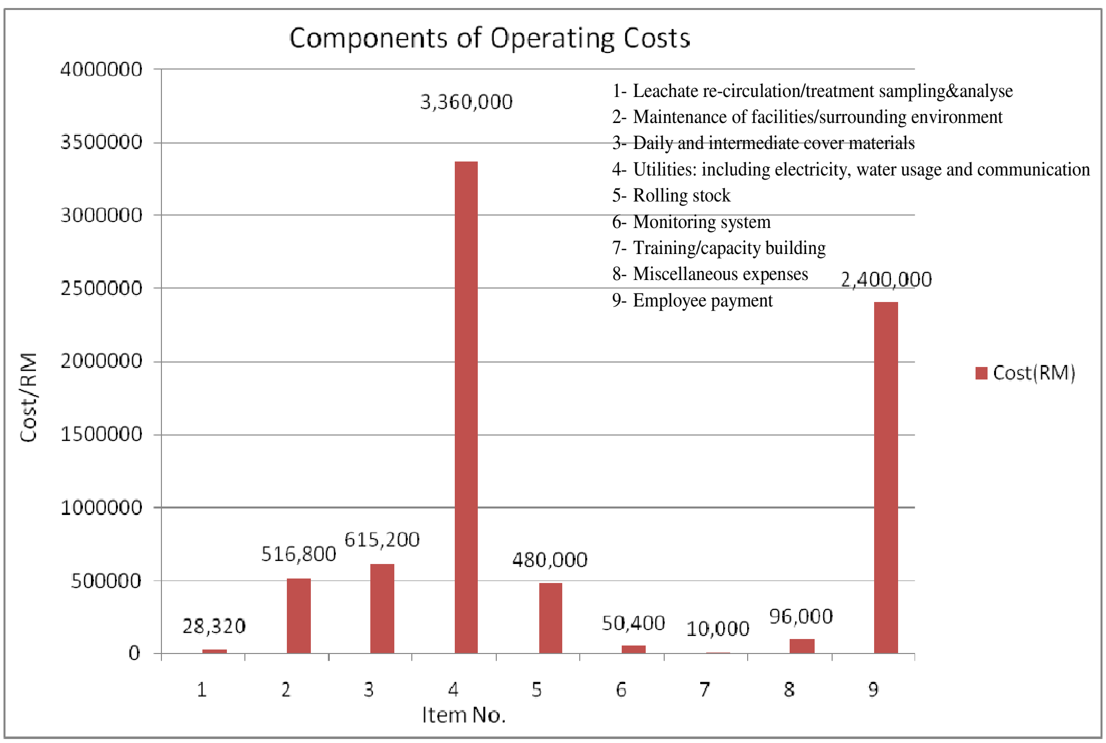

Figure 5.7 Components of Operating Costs of Landfill B (Annual Average)

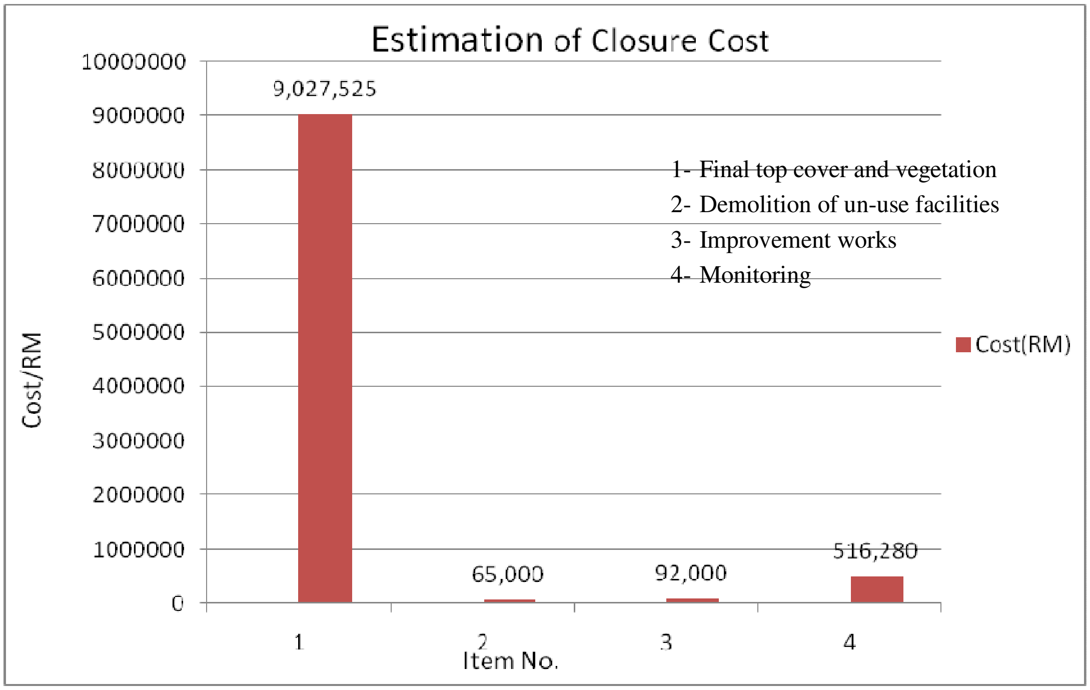

Figure 5.8 Components of Closure Costs of Landfill B (Annual Average)

The main environmental revenue for a sanitary landfill will be the tipping fee per tonne of garbage deposited to the landfill site. There are different standards charges for waste collection:

- Normal waste from Government: RM36/tonne
- Normal waste from Private: RM50/tonne
- Fiber and CSR: RM200/tonne
- Others: more than RM200/tonne

Therefore, it is assumed that the average tipping fee in Landfill B is RM 36 per tonne. If the same amount of garbage is not collected, clean up cost will definitely increase five times, as shown in a hypothetical case obtained from DOE database (Table 5.4):

Table 5.4: Cost of Cleanup versus Environmental Revenue

Item	Details	Cost (RM)
1	Unit cost of labor @ RM50 per day for clean up Assume 2 persons for one day	100
2	Cost of rehabilitating the garbage site through truing @ RM 10 per m^2 Assume 100 m^2 and one ton of garbage	100
3	Transport of the garbage to dumpsite	20
Total		220
Clean up divided by Environmental Revenue		5.5 times

(Source: DOE, 2007.)

Besides the above economic evaluations, there are socio-economic costs and benefits that will potentially accrue to the project proponent, the Government and the communities. These can be categorized into quantifiable and non-quantifiable benefits and losses. These include more money in circulation per household, which can be translated into higher standard of living and higher purchasing power. All these will be examined following the list below:

a) Employment benefits ;
b) Deterioration in environmental quality;
c) Social costs arising from occupational and traffic accidents; and
d) Nuisances and other inconveniences that will affect the psychological well-being of the local population.

Besides the revenue, it is known that Landfill B is proposing to invest a new technology that converts bio-gases into power from 2012. It will decrease electricity bills and enhance the environmental benefit. The estimated economic benefits including revenue, waste recycling and power generation are illustrated in Figure 5.9.

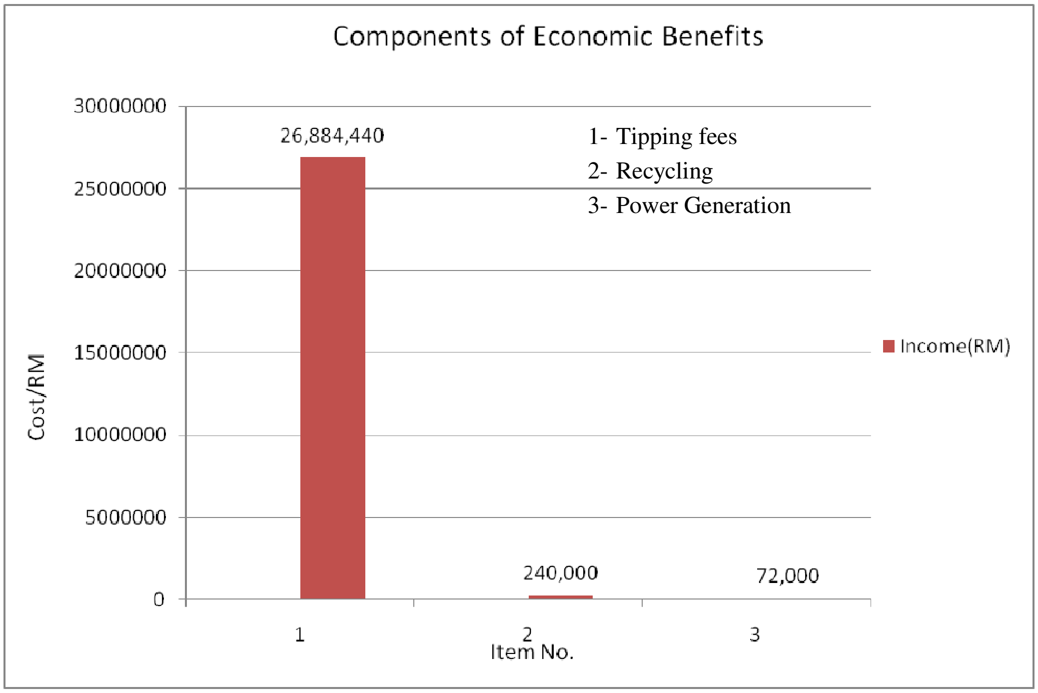

Figure 5.9 Components of Average Annually Economic Benefits in Landfill B

A general statistic of the quantifiable and non-quantifiable economic, social and environmental gains and losses of Landfill B can be summarized in Table 5.5. The overall costs and benefits of Landfill B during actual operation period can be stated as Table 5.6. While the cost-benefit analysis figure of Landfill B is illustrated in Figure 5.10.

Table 5.5 Summary of the Quantifiable and Non-Quantifiable Economic, Social and Environmental Gains and Losses in Landfill B

No.	Descriptions	Gains	Losses
1	In line with Ninth Malaysia Plan, 2006-2010	/	
2	Compatible with the committed landuse for '*Blok Perancangan Kecil 2.1f (BPK 2.1f)*' as stipulated in the *Draf Rancangan Tempatan Majlis Daerah Kuala Selangor 2015*	/	
3	Bring a transfer of new technology in terms of waste management in the District and the country	/	
4	Provide improved management and control of more hygienic waste disposal facilities	/	
5	Improve the existing infrastructures, facilities and amenities to cater for the Sanitary Landfill development	/	
6	Employment opportunities	/	
7	Increase in opportunity cost	/	
8	Spin-off benefits will ensure the sustainability of income of the local population	/	
9	Positive perception of the Project by the local community	/	
10	The project is compatible to the surrounding landuse	/	
11	Loss of agricultural land		/
12	Reduced environmental quality		/
13	Social costs arising from occupational and traffic accidents		/
14	Impacts on the psychological well-being of the local populations		/
	Total	10	4

Table 5.6 Demonstrating Landfill B Cost and Environmental Benefit

Operation year	Total cost(RM) (Construction + Operation)	Total Benefits (RM)
2007	23,377,368	18,000,000
2008	24,071,120	19,800,000
2009	24,834,247	21,780,000
2010	25,673,687	23,958,000
2011	26,597,071	26,353,800
2012	28,120,132	29,061,180
2013	29,719,346	32,039,298
2014	30,998,521	35,315,228
2015	32,341,655	38,918,751

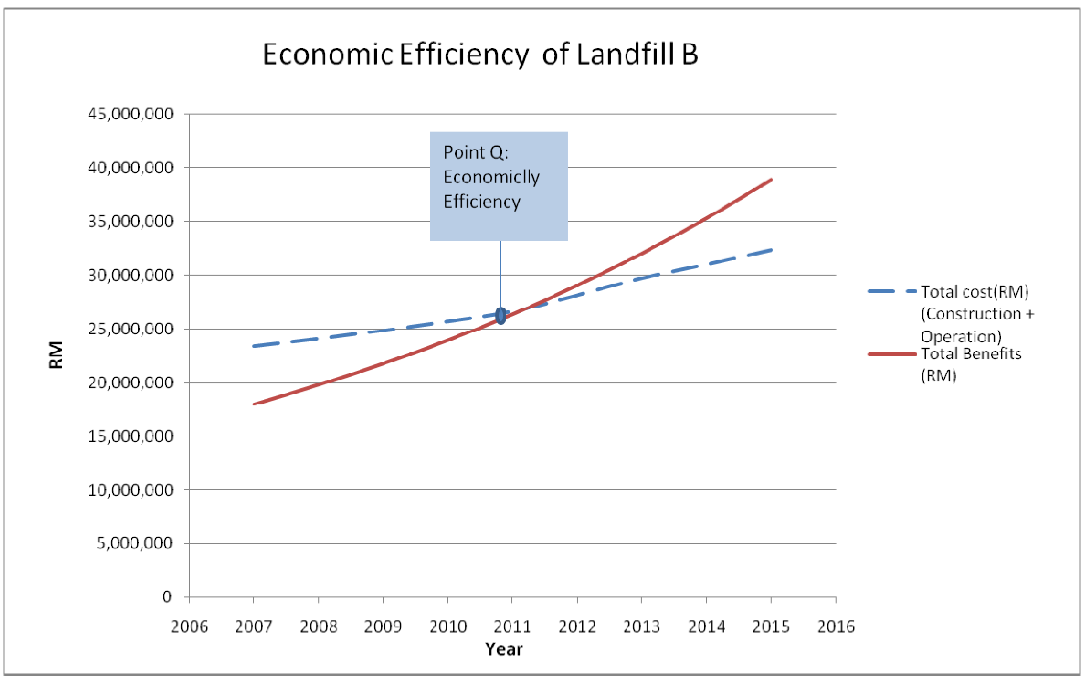

Figure 5.10 Graph Depicting Economic Efficiency of Sanitary Landfill B

The graph (Figure 5.10) is based on the calculation and estimation of the overall costs during the actual operational life span. In this economic evaluation model, the total costs are divided into construction expenses, operation expenses and maintenance cost. Landfill B was proposed to last for 16 operational years. However, because of the rapid waste generation growth rate, Landfill B operation was overloaded when it was opened. The calculations and estimations of Landfill B are mainly from the revenue of tipping fees, waste recycling and power generation from biogases over an 8 years period.

Landfill B can achieve economically efficiency point Q after 5 operational years. Therefore, it proves that Landfill B is an effective waste disposal system. In this graph, the costs keep increasing because of various factors, which include the net present value and the internal return rate. A steady growth of economical and environmental benefits can be indicated in the graph (Figure 5.10). New green technology application and bio-gases power generation improve the benefits of both aspects significantly.

Though there is a steady increase of the existing benefit, the costs of landfill construction and operation, and new technology investment still outstrip the value of benefits. It is recommended to introduce different approach of final waste disposal like incineration and composting. New green technologies can generate power from incineration of waste or bio-gases conversion from landfills. Landfill itself can benefit from the internal power generation and reduce the operational cost.

5.4 Uncertainties

Since the study is involved operational and financial aspects, some information about technical and economic aspects has to be estimated based on average market value to avoid the impacts of market competitions. In reality, some values could be different with different location, currency rate changes, time and distance alteration.

In this research, all benefits gained by landfills are from direct aspects. Indirect benefits are not presented in the data gathering. It is know that proper closure of landfill sites can gain significant benefits including reduction of the risks to environment and public health, though it is impossible to be quantified.

5.5 Comparisons between FM System (Landfill A) and Reformative Semi-Aerobic Sanitary Landfill (Landfill B)

According to the above technical and financial investments including cost-benefit analysis, a comparison between Landfill A and Landfill B is indicated in Table 5.7 and table 5.8.

Table 5.7 Technical Considerations of Landfill A and Landfill B

No.	Item	Landfill A (FM system landfill)	Landfill B (Reformative landfill)
1	Type	Typical Semi-aerobic	Partial Semi-aerobic
2	Precipitation Requirement	It has minimal requirement of water content. From the above statements, it is suitable for Malaysian circumstance.	Malaysia is heavy with rainfall. Even in the dry season, the precipitation still keeps in a considerable level.
3	Temperature Requirement	Need to be controlled with 15℃ - 40℃ to maintain the efficiency. Cooling system is installed in tropical countries.	Daily average operation temperature is 36℃. The peak point can reach over 40 ℃ . There is no cooling system.
4	Landfill gas control and monitor system	Landfill gas generation is monitored and analyzed quarterly. However, there is no collection facilities for FM.	There is no landfill gas monitoring system. A research has been conducted to monitor and collect data for power generation since 2011.
5	Leachate treatment system	It is required that the excess interstitial water needs to be removed upon generation. High requirement of facilities and installations. High efficiency of leachate collection. High quality of leachate generation. Leachate circulation system.	Moderate requirement of leachate collection and treatment system. Leachate quality is below standards but the value is higher than Landfill B.

Table 5.8 Financial Considerations of Landfill A and Landfill B

No.	Item	Landfill A (FM system landfill)	Landfill B (Reformative landfill)
1	Construction	Low investment in the basic construction. It is suggested that local or reusable materials are used as raw materials.	High construction cost. Facilities and materials were imported from other countries like Japan and USA.
2	Operation	High requirements of professionals. Annual external training is necessary. Therefore, the payment and training cost is higher. Operation cost is considerable.	Moderate requirements of operation workers. There are many outside contractors and consultants supporting the normal operation. Basic requirement for training. Contractors and outside consultants can reduce the operation cost and bring economic benefits to Landfill B. A new technology is proposed to implement to convert landfill gases to electricity. It will reduce the cost continuously.

(Con't)

Table 5.8 Financial Considerations of Landfill A and Landfill B

No.	Item	Landfill A (FM system landfill)	Landfill B (Reformative landfill)
3	Closure	Direct and indirect benefits. Low tech and low cost of closure.	High requirements and cost of closure to make sure the land can be reused for other purpose after certain period.
4	Economically efficiency	It can reach the balance point after 10 years operation period. It is suitable for building up a primary sanitary landfill or converts open-dumps into proper landfill to reduce the environmental impacts and risks to human health.	It can reach the balance point after 5 years operation period. In the market, landfill B has higher competed ability. However, it is not the best choice to start with basic MSW management development because of the high initial investment.