4 MODELLING OF MUNICIPAL WASTE MANAGEMENT SYSTEM VIA SWPLAN APPLICATION

4.1 Introduction

Advancement in technology had enhanced the quality of life of a society. It had created a more pleasant environment to live in (Odum and Odum, 2006) with improved facilities and better infrastructures. Most developed nations are benefiting from the urbanization while in less developed countries, urbanization jeopardizes the environment (Firman, 2009; Fauziah and Agamuthu, 2009). Most developing and under developed countries are not able to cope with mega- urbanization due to lack of infrastructure, proper planning and technologies, as well as inconsistency in waste management data (Chowdhury, 2009; Fauziah *et al*., 2004). Among the biggest impact of rapid urbanization is the increase in waste generation.

The Asian region contains most of the developing countries where progressive economic activities are taking place. The higher the rate of development of a nation the higher is the generation of waste (Odum and Odum, 2006; Agamuthu *et al*., 2004; Fauziah *et al*., 2004; Agamuthu, 2001). The high generation of waste is acceptable and manageable if appropriate measures had been implemented in minimizing the cost and impacts to the environment. However, this is not the scenario observed in less developed and developing countries where economic considerations stand a much higher ground than environmental concerns. Various detrimental effects to the environment are faced by these nations due to lack of proper planning and unavailability of appropriate

technologies (Firman, 2009). Malaysia spends approximately USD26.32 million (RM1 billion) every year to manage the 3% annual waste increase (Agamuthu *et al*., 2004). In the state of Selangor, the generation of MSW is projected to exceed 3100 tonnes in 2017 (Agamuthu *et al*., 2004). Therefore, it is essential that appropriate technologies are integrated into the waste management system to optimize all factors, as well as, to create a cost-effective system.

Various tools had been applied in determining the best and the most cost-effective waste management system. A Geographic Information System (GIS) routing model was utilized to identify the most optimal routes and locating waste management infrastructure at the lowest available cost involving factors such as population density, waste generation capacity, networks and types of road, collection vehicles and others (Ghose, *et al*., 2005; Shmelev and Powell, 2005). Skordilis (2004) combined life cycle analysis (LCA) with the worth benefits utility analysis (WBU) to produce an efficient method of waste disposal. Application of LCA through GreenPro-1 improves the process design and decision making from a multi-criteria consideration (Khan *et al*., 2002). These tools managed to enhance best decision-making in waste management. It allows simulation of scenarios at various affecting factors. This study was conducted to design the most cost effective MSW management system with the application of SWPlan in Selangor, Malaysia.

SWPlan is one of a planning tool utilized by solid waste management professionals to compare the cost of MSW management options. This software can be applied to simulate

an integrated solid waste management at the most effective cost level. The objectives of this chapter include:

1. to use SWPlan to study the current MSW management for urban, sub-urban and rural area in Selangor;
2. to evaluate the existing waste management system in Selangor; and
3. to simulate the efficiency if the waste management improvement target for 2020 such as 22% recycling is achieved.

Following sections discuss the methodology in achieving these objectives.

4.2 Materials and Methods

Waste composition studies were conducted at three landfills in Selangor where the waste received by these landfills were analysed and averaged. Types of landfills involved in this study include urban, sub-urban and rural landfills as listed in Table 4.1.

Table 4.1: Landfill types and the average tonnage of waste daily.

Area	**Landfill Studied**	**Daily Average Tonnage of Waste**
Urban	Kundang	300
Sub-urban	Sungai Sedu	200
Rural	Panchang Bedena	60

Weight of food wastes, mixed paper, newsprint, white paper, corrugated paper and others, plastics film and others, glass, metal items, bi-metal cans, aluminium cans and others, textile, rubber, yard waste and miscellaneous, were determined for SWPlan application. Besides the values of waste composition of required waste categories, other information including population, percentages of the sources of waste and cost of waste collection

were also computed in the SWPlan application. The flow diagram of the procedures is shown in Figure 4.1.

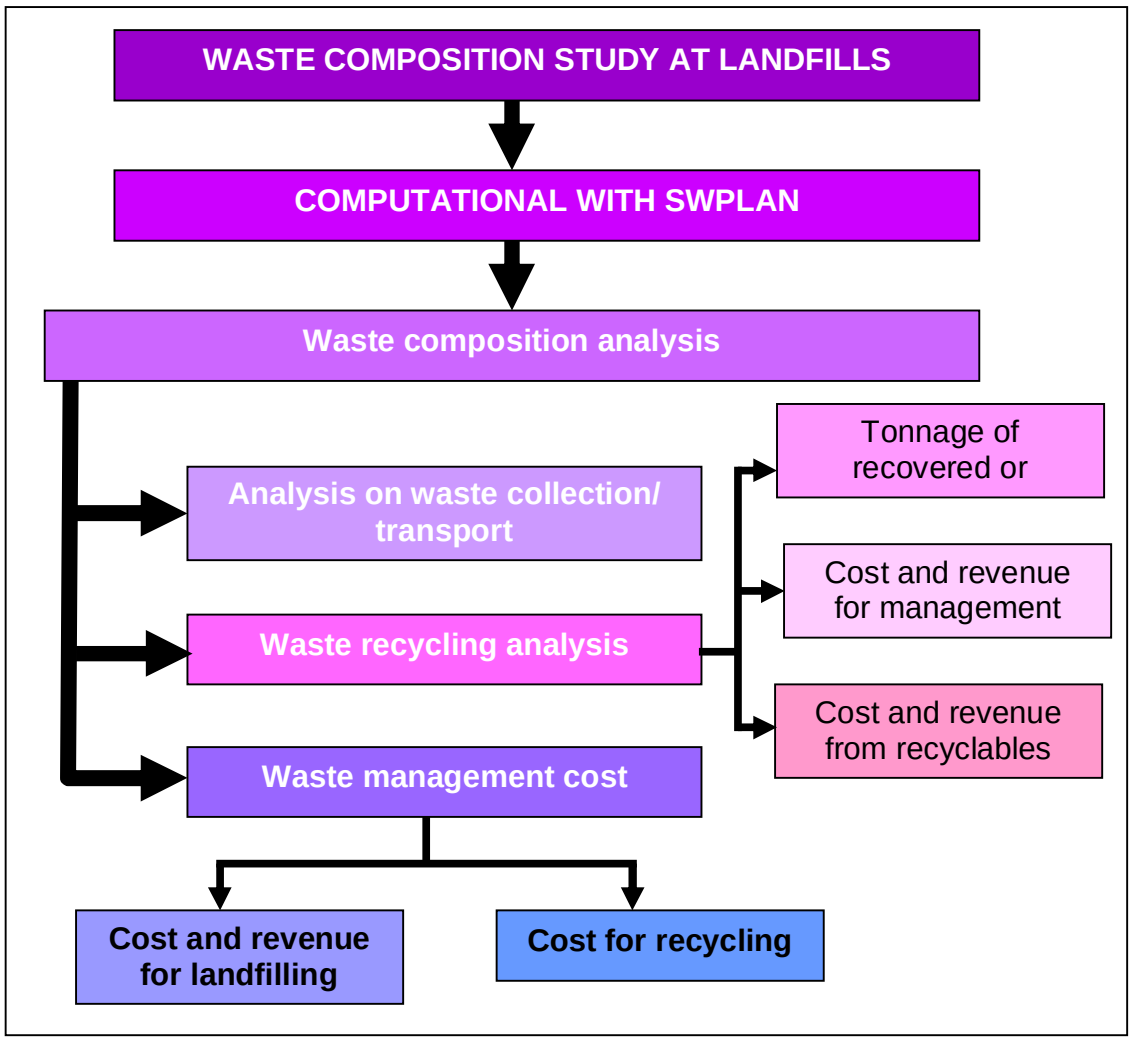

Figure 4.1: Flow diagram of SWPlan procedures for MSW management modelling.

Best waste management practices were computed for rural, sub-urban and urban areas. Also analyzed were the current waste management practices in Selangor, and future status for 2020 with the assumption that recycling is at 5% and 22% (Government's target for year 2020), respectively.

4.3 Results and Discussions

4.3.1 Waste Composition Analysis

The largest portion of waste in Selangor is food waste with annual generation of 630,830 tonnes, as illustrated in Appendix 4.1. It is followed with paper and plastic at 166,300 tonnes per year and 133,310 tonnes per year, respectively. The waste composition indicates a transition state observed in rapidly developing countries (Zhu *et al*., 2009; Körner *et al*., 2008; Agamuthu *et al*., 2004; World Bank 1999).

Food waste increased from the rural areas (5,683 tonnes) to the urban (94,754 tonnes). Other types of waste including paper, bimetal cans, glass, garden waste, and textile also indicated trend similar to food waste generation. Obvious trends are observed in paper waste composition where urbanization increased the generation of paper. Similar observations were reported in developing countries like China, Taiwan, India and Kenya (Wang *et al*., 2009; Wang *et al*., 2009a; Talyan *et al*., 2008; Henry *et al*., 2006). On the contrary, the generation of plastic has no particular trend. Less plastic waste are generated in the sub-urban area than that in rural and urban areas. Annual MSW generation derived from SWPlan application for areas in Selangor is detailed in Table 4.2.

More than 50% of the waste originated from the commercial centers (Figure 4.2). Sub-urban area has the highest waste portion (84%) sourced from commercial sector while urban has the lowest (52%).

Table 4.2: Annual MSW generation (tonnes) from rural, sub-urban and urban areas in Selangor, using the SWPlan application.

Waste types	Rural	Sub-urban	Urban	Selangor (Average)
Newspaper	403	1,410	2,555	40,160
Corrugated paper	1,439	4,216	3,650	60,723
Mixed paper	1,139	4,104	18,980	46,646
Office paper	92	146	493	12,421
Magazine	0	176	0	4,692
Phone book	0	0	0	1,656
Aluminum cans	28	301	183	2,346
Other aluminum	0	0	37	1,242
Bimetal cans	552	3,890	6,077	17,803
Ferrous metal	149	25	329	9,936
Non-ferrous metal	2	55	0	2,346
Glass	247	537	1,789	35,330
Plastic film	3,614	2,218	8,304	73,833
Rigid plastic	3,351	2,098	5,074	59,481
Garden waste	1,794	7,830	8,395	119,790
Food waste	5,683	8,567	94,754	630,828
Wood	101	3,493	1,825	11,731
Textile	480	954	14,637	35,606
Rubber	197	3,042	1,551	16,975
Miscellaneous	2,630	7,132	13,870	196,521
Total	21,901	50,194	182,503	1,380,066

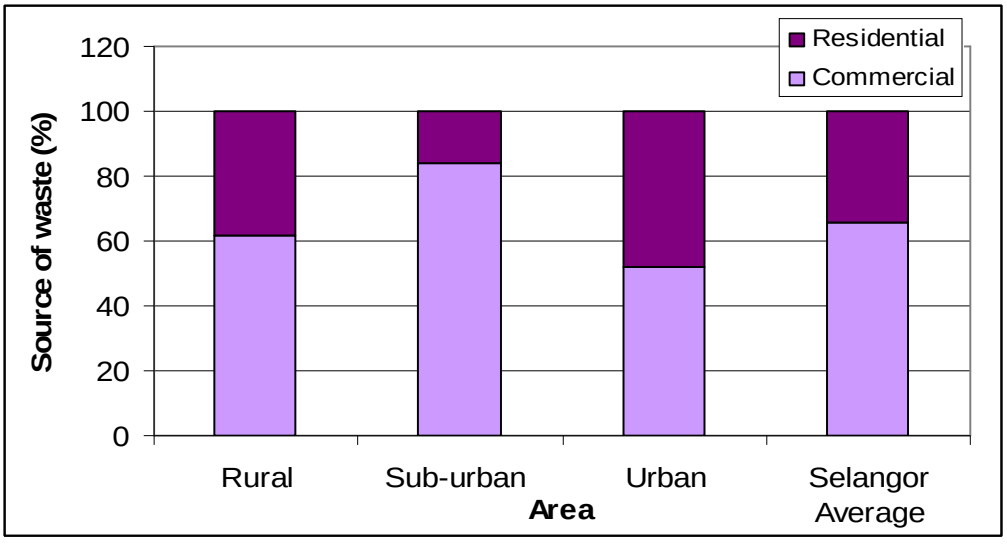

Figure 4.2: Source of waste generated in Selangor (%).

In Selangor, waste sourced from commercial areas almost doubled the waste generated by the residential sector. Waste from commercial sector totaled approximately 0.9 million tonnes indicating that vast area in Selangor are covered with commercial activities while residential sector contributed approximately 0.5 million tonnes. The subsequent sections discuss the result obtained from the analysis of waste collection and transportation.

4.3.2 Analysis on waste collection/transport

Waste management contractors service 50% to 90% of the area, as indicated in Table 4.3. The local council or the municipality caters the waste collection for the remaining area. The shifting of waste management service from the local government to private bodies was the major change in the country's waste management service since 1982. The main objective of this action was to improve the efficiency of waste management in the country (Agamuthu *et al*., 2009; Fauziah and Agamuthu, 2007; MHLG, 2003).

Table 4.3: SWPlan output on waste collection and waste transportation in Selangor.

	Rural	Sub-urban	Urban	Selangor (Average)
Coverage of contracted area	90%	50%	60%	60%
Cost for contracted area (per annum)	RM438,088	RM236,324	RM3.1 million	RM16.7 million
Waste and recyclables collected (per annum)	21,349 tonnes	49,234 tonnes	180,127 tonnes	1.4 million tonnes
Waste and recyclables collection cost (per annum)	RM1.1 million	RM2.9 million	RM9.7 million	RM115 million
Waste and recyclables collection cost/tonne	RM56	RM59	RM54	RM84.00
Commercial on-site collection cost	-	RM705	RM14,668	RM0.14 million
Drop-off center collection cost	RM9,996	RM18,454	RM31,441	RM0.25 million

1 USD = RM3.5

Subject to sensitivity and confidentiality of data, waste managers in Selangor refused to reveal their management cost. Therefore, the SWPlan application is utilized to estimate the current waste management cost based on the average cost incurred by waste managers in Malaysia. Accurate comparison with the actual cost of waste management in Selangor is not possible.

As a result of privatization, cost incurred for collection and transportation increased. Approximately RM16.7 million is spent by the local government to cover the collection cost by waste contractors per year. Sub-urban sector incurred the lowest collection cost (RM236,324) due to the lower percentage of area covered by the local government. Both rural and urban areas spent RM438,088 and RM3.1 million, respectively, to cover the collection cost due to the large area covered for waste management. It is unavoidable since it is the policy of the government to continuously improve the efficiency of waste management system.

The tonnage of waste including recyclable materials collected in Selangor amounted to 1.4 million tonnes per annum. The calculation is based on the coverage area of collection service and the waste generation within the area. The collection was observed to increase from rural area to urbans. This can be explained since waste generation is higher in urban areas that more frequent waste collection is required. In addition, the higher standards of living of the urbanites demand more efficient waste collection system (Odum and Odum, 2006). This resulted with higher waste collection cost. The annual collection cost for Selangor was calculated to reach RM115 million. The cost in rural area was the lowest

due to the low volume of waste generated. The collection cost per tonne among rural, sub-urban and urban areas is approximately RM54-RM59. There is no significant difference as charges imposed on waste collection services is unlikely to vary much. On the contrary, collection cost per tonne in Selangor was RM84. This is taking into consideration the cost factors in all parts of the state.

Collection of recyclables assuming current recycling rate at 5%, varied from one area to the other. The collection cost for commercial on-site area was lower due to reduced number of personnel required to manage the site than that required for drop-off center. The annual collection cost for commercial on-sites in Selangor was approximately RM0.14 million while for drop-off centers it was approximately RM0.25 million. The collection centers are important as it promotes higher rate of recycling among the community. Following section discusses the findings from waste recycling analysis.

4.3.3 SWPlan Analysis on waste recycling

The largest percentage of recyclable for Selangor's average was plastic film at 21%, which contributed approximately 3,670 tonnes per year, followed by corrugated paper (17%) and rigid plastics (17%). However, in the urban area, the largest percentage is mixed paper (40.6%) while in the sub-urban sector it is corrugated paper and in rural area it was rigid plastic at 22% and 31%, respectively. Table 4.4 represents the current percentage of recycled MSW in Selangor areas derived from SWPlan, based on the assumption that recycling is at 5%.

Table 4.4: MSW recycled material in Selangor (annually) computed using SWPlan (%).

Recyclables	Rural	Sub-urban	Urban	Selangor (Average)
Newspaper	3.7	7.4	5.5	11.4
Corrugated paper	13.4	22.1	7.8	17.2
Mixed paper	10.6	21.4	40.6	13.2
Office paper	0.9	0.8	1.1	3.5
Magazine	0	0.9	0	1.3
Phone book	0	0	0	0.5
Aluminum cans	0.3	1.6	0.4	0.7
Other aluminum	0	0	0.1	0.4
Bimetal cans	5.1	20.3	13	5.1
Ferrous metal	1.4	0.1	0.7	2.8
Non-ferrous metal	0	0	0	0
Glass	0	2.8	2.3	6
Plastic film	33.6	11.6	17.8	21
Rigid plastic	31.1	11	10.9	16.9
Garden waste	0	0	0	0
Food waste	0	0	0	0
Wood	0	0	0	0
Textile	0	0	0	0
Rubber	0	0	0	0

No trend is observed in terms of recyclable percentages from rural to urban areas, except mixed paper. Mixed paper indicated an increasing trend where urban area generated more of this material than rural and sub-urban areas. This is mainly due to the lack of source separation where all types of paper are disposed off together resulting with the generation of mixed waste. This probably was due to lack of knowledge and awareness among the community to conduct proper waste separation. It was reported that most Malaysians are aware of recycling but they lack proper understanding of issues pertaining to recycling activities (Chenayah *et al*, 2007). This results in abundant recyclables being wasted into the waste stream. Figure 4.3 illustrates the tonnage of recyclables available, recovered by recycling, or disposed into landfill.

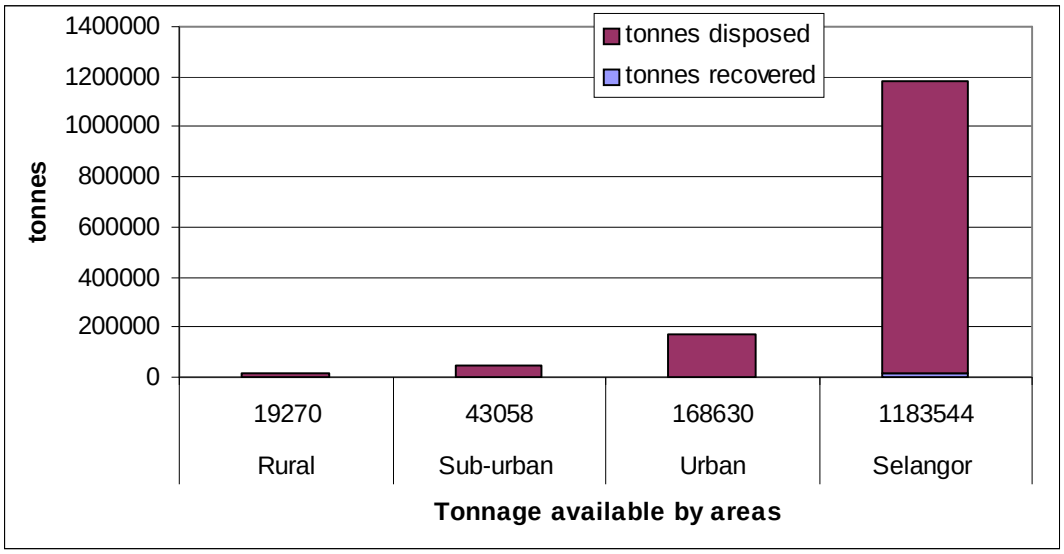

Figure 4.3: Tonnage of recyclables available, recovered by recycling, or sent for disposal in Selangor annually (as per generated by SWPlan).

From a total of 1,183,544 tonnes of recyclables available in the MSW stream in Selangor per year, only 18,222 tonnes are processed for recycling while the remaining portion is disposed of into the landfills, based on the assumption that 5% of total waste generated is recycled. The collection of these recyclables is mainly (69%- 100%) from drop-off centers rather than from commercial on-site collection centers (0%-31%). The cost and revenues from recyclable collection center is shown in Table 4.5.

Table 4.5: Cost and revenues of recyclables from collection centers generated by SWPlan.

Commercial on-site	Rural	Sub-urban	Urban	Selangor
Recyclables processed in commercial on-site (tonnes per day)	-	35	744	4,019
Collection cost in commercial on-site (per day)	-	RM705	RM14,668	RM135,198
Recyclables processed in drop-off center (tonnes per day)	551	921	1,630	14,295
Collection cost in drop-off centers (per day)	RM9,996	RM18,454	RM31,441	RM250,333
Collection cost per tonne	RM18	RM20	RM19	RM21
Transportation cost per tonne	RM8	RM10	RM10	RM9

Table 4.5 indicated that the collection cost increased with increased tonnage of recyclables. Among the three areas, urban sector has the highest tonnage of collected recyclables (1630 tonnes) resulting with very high collection cost (RM31,441). This is mainly due to the participation among urbanites in recycling activities. Studies indicated that community in Malaysia particularly in urban areas is more willing to participate in recycling activities if recycling facilities are made available (Chenayah *et al.*, 2007; Fauziah and Agamuthu, 2007; Irra, 1999). This is so because awareness on recycling has been instilled through intensive campaigns by local government and NGOs in urban areas. On the contrary, this is still lacking in the sub-urban and rural sector that recycling is still low.

The collection cost per tonne for recyclables is highest in the sub-urban area, as compared to rural and urban. This is likely due to the longer distance it takes to send the recyclables to the recycling center, which is generally located in the cities (urban) or isolated places (rural). The revenue obtained from marketing the recyclables based on SWPlan is detailed in Table 4.6 while the revenues according to the type of recyclables, are illustrated in Appendix 4.2-Appendix 4.4.

Table 4.6: Revenue and cost from recyclables computed using SWPlan for areas in Selangor.

	Rural	Sub-urban	Urban	Selangor
Gross revenue per annum	RM30,223	RM45,606	RM83,408	RM864,167
Gross revenue per tonne	RM35	RM48	RM55	RM47
Transportation cost per annum	RM15,067	RM12,935	RM7,452	RM163,981
Net revenue per annum	RM63,341	RM32,671	RM22,772	RM700,186
Net revenue per tonne	RM29	RM34	RM42	RM38

Urban area obtained the largest revenue from marketing of recyclables. This is mainly due to the fact that the largest tonnage of recyclables are from the urban areas. The existing commercial on-site collection centers and drop-off centers resulted with more efficient and cost-effective collection system than that in rural and sub-urban areas. Commodities available and recycled is illustrated in detailed in Appendix 4.1-Appendix 4.4. The data obtained from SWPlan indicated that recycling, even at a very low percentage (5%) can generate revenue to waste managers. However, it is crucial that some awareness and knowledge are instilled among the society that source separation taken place prior to the collection so that the collection cost can be reduced. Consecutive sections discuss the waste management costs incurred in all areas in Selangor.

4.3.4 Analysis on waste management cost using SWPlan

Waste management cost was found to differ from one area to another according to the tonnage of waste involved. However, there is so significant difference in the average cost per tonne incurred, regardless of the location of the area. Table 4.7 depicts the management methods and the tonnage involved in areas in Selangor as computed using SWPlan.

Table 4.7: Data obtained from SWPlan computations for waste management in Selangor.

Management method		Rural	Sub-urban	Urban	Selangor
Tonnage collected for processing (tonnes per annum)	Landfilling	21,362	49,234	180,127	1,361,752
	Recycling	551	956	2,373	18,313
Net tonnage processed (tonnes per annum)	Landfilling	21,364	49,239	180,138	1,361,843
	Recycling	548	951	2,362	18,222
Rejected recyclable (tonnes per annum)		3	5	12	92
Rejects transportation cost (per tonne)		RM22	RM47	RM116	RM828

The existing waste management methods in Selangor are mainly landfilling and recycling, based on estimates of recycling rate at 5% while remaining 95% are disposed into landfills (Agamuthu *et al*, 2009). Generally, more than one million tonnes of waste are disposed off into landfill in Selangor. Sub-urban sectors disposed more than double the waste (49,234 tonnes) disposed in rural areas (21,362 tonnes). On the contrary, urban area disposal almost quadrupled (180,127 tonnes) in sub-urban sector. This is due to the increase in waste generation as a result of urbanization (Haberl, 2006; Agamuthu *et al*., 2004).

Current tonnage of recyclables processed for recycling in Selangor is 18,222 tonnes per annum. Net recyclables weight in urban area is 2,362 tonnes, which is very much higher than rural (548 tonnes) and sub-urban sectors (951 tonnes). However, this is very low as compared to other urban areas in the world.

Cities like Delhi in India recycled more than 30% of the waste while in Singapore recycling rate had almost reach 50% (Shekdar, 2009; Pappu *et al*., 2007). The low recycling rate in Selangor is generally due to the low participation in recycling activities among the public. In addition, the absence of a clear policy in regards to recycling and waste reduction does not encourage recycling among Malaysians. Therefore, the major portion of the waste are disposed off into landfills. Consequently, the cost incurred to manage landfills also increased. Table 4.8 lists the cost required for landfilling activities generated using SWPlan for areas in Selangor.

Table 4.8: Costs and revenue for landfilling activities incurred at different areas in Selangor (generated using SWPlan)

Cost for landfilling	Rural	Sub-urban	Urban	Selangor
Total facility cost per annum	RM1,580,965	RM3,645,656	RM13,332,879	RM100,828,416
Annual debt service cost	RM161,025	RM371,318	RM1,357,983	RM10,269,597
Annual operation cost	RM533,802	RM1,230,973	RM4,503,461	RM34,076,078
Gross cost per annum	RM694,827	RM1,602,291	RM5,861,445	RM44,315,675
Revenue per annum	RM0	RM0	RM0	RM0
Net cost per annum	RM694,827	RM1,602,291	RM5,861,445	RM44,315,675

The total facility cost for landfill management differs according to the location of the landfill and the capacity it requires to accommodate. Landfill in urban area has the highest total facility cost. This probably was due to the high price for land, as well as, the size of land required.

The total facility cost for landfilling in Selangor reaches RM100 million due to the fact that many existing landfill in Selangor are located in urban areas or at the outskirt of township which has high land-value. This resulted with high annual debt service cost, as most municipality or waste managers do not posses sufficient asset to cover the total facility cost as well as the operating cost. The annual operation cost in Selangor reaches RM34 million. Even waste management in rural area incurs RM0.5million, regardless of the lower land-price and smaller landfill capacity. This resulted with high gross cost for landfilling activities.

As computed using the SWPlan, there is no revenue obtained from landfilling activities in Selangor. It has been reported that most municipalities in Malaysia spend almost 70% of their income for waste management (Agamuthu *et al*., 2004; Fadil and Mohd. Badruddin, 2002). Therefore, it is essential to incorporate other waste management options in order to create some revenue for the waste management provided. Among others is recycling. Table 4.9 indicates the cost of recycling and revenue obtained at different areas in Selangor, calculated using the SWPlan.

Table 4.9: Cost for recycling at different areas in Selangor (generated using SWPlan).

Cost for recycling	Rural	Sub-urban	Urban	Selangor
Total facility cost per annum	RM8,075	RM13,935	RM35,065	RM264,103
Annual debt service cost	RM822	RM1,419	RM3,571	RM26,899
Annual operation cost	RM9,912	RM17,206	RM42,721	RM329,642
Transportation cost (rejects and products) per annum	RM7,473	RM12,982	RM15,183	RM164,809
Gross cost per annum	RM18,208	RM31,607	RM61,476	RM520,914
Revenue per annum	RM30,223	RM45,606	RM83,408	RM864,167
Net cost per annum	RM-12,015	RM-13,999	RM-21,932	RM-343,253
Net cost per tonne	RM-21.93	RM-14.72	RM-9.09	RM-18.84

The total facility cost varies from rural to urban areas where the lowest facility cost is in rural area at RM8,075. The cost increased accordingly with urbanization due to the increase price of land, as well as, the increased capacity of the facility. The total facility cost for Selangor is RM264,103 which takes into consideration all facilities in the state, regardless of its location. The annual debt service cost was not as high as that of landfill. This is due to the fact that the original cost incurred is lesser than setting up landfill facility. Therefore, the annual operation cost was also relatively low than that of

landfilling. It is mainly due to the low maintenance cost in managing recyclables as compared to managing waste disposal into landfills.

Annual operation cost of recycling ranged from RM9,912 in rural area compared to RM42,721 in urban area. Unlike landfilling, transportation cost is involved in recycling particularly in transporting rejects to landfill and products to markets. Hence transportation cost increased with increased tonnage of recyclables. In Selangor the transportation cost of recycling is RM0.16 million. Gross revenue from recycling activities ranged from RM18,208 in rural area to RM61,476 in urban area. This is due to the difference in tonnage of recyclables received as well as the distance involved in materials collection and products marketing. Urban area has larger tonnage of recyclable in addition to the abundance of recycling markets within short-distance of the landfill. The market for recyclables has improved over the years particularly in urban areas from various campaigns by government and NGOs locally and globally (Woodard *et al*., 2006; Fauziah and Agamuthu, 2005; Perrin and Barton, 2001; World Bank, 1999). Revenues from the recycling activities ranged from RM30,223 in rural area to RM83,408 in urban area while the total revenue generated from recycling activities in Selangor reached almost RM0.9 million annually. With the revenue obtained from the recycling activities, the net cost and the net cost per tonne are negative. This indicated that recycling may reduce the expenditure in landfilling and reduce the net cost incurred by landfill managers.

The revenue can be further improved if more waste management options with revenue generation are incorporated into the waste management system. Consecutive sections discuss the waste management costs required if the targets for 2020 waste management system is implemented.

4.4 Simulation of waste management costs using the proposed targets for 2020 waste management system

The larger part of MSW is generated by commercial source (66%). The annual MSW generation used for this simulation is approximately 1.4million tonnes. Appendix 4.5 illustrates the detailed computations of the data using SWPlan. Largest percentage of waste generated is food waste at approximately 46%. The trend in generating high percentage of food waste is expected to take place continuously until the Solid Waste and Public Cleansing Management (SWPCM) Act 2007 comes in place. Similarly with other wastes, particularly packaging wastes, the generation will only be reduced after SWPCM implementation. This is because the Act imposes actions pertaining to waste reduction where industries would be responsible for their packaging waste. However, since the bill is yet to be implemented, current trend in waste generation is expected to continue with an annual increase of 3% (Agamuthu *et al*., 2009). The waste collection on the other hand is mainly by commercial open and municipal contractors who cater approximately 66% and 21%, respectively. Table 4.10 details the waste collection system and costs incurred for waste collection as computed using SWPlan for Selangor.

Table 4.10: Waste collection data for Selangor from SWPlan computations.

Waste collection	Tonnage	Collection cost	Collection cost/ tonne
Residential open	18,347	RM366,950	RM20
Residential municipal	128,432	RM5,779,459	RM45
Municipally contracted	220,170	RM13,210,193	RM60
Commercial open	712,314	RM56,985,145	RM80
Total	1,079,264	RM76,341,746	RM71

The largest expense for waste collection is by commercial open and municipal contractors at RM56,985,145 and RM13,210,193, respectively. This is due to initiatives to improve waste collection efficiency as targeted in the 2020 waste management system.

As for recyclables collection, the largest contributor is expected from drop-off center covering approximately 92% of the total recyclable item collections. Table 4.11 depicts the recyclables collection and cost incurred as generated by SWPlan for Selangor.

Table 4.11: Recyclable items collection for 2020 target as computed by SWPlan for Selangor.

Recyclables collection	Tonnage collected per annum	Collection cost per annum	Collection cost/tonne
Commercial on-site	19,463	RM596,971	RM31
Drop-off center	228,854	RM2,732,541	RM12
Total	248,317	RM3,329,512	RM13

The collection of recyclables is cheaper with drop-off centers at RM12/tonne than that of commercial on-site collection. Collection cost for commercial on-site is more than double the cost at drop-off center. This is due to the higher maintenance of the commercial on-site center as it would also include rental and manning cost.

Based on the recycling analysis, the largest component in recycling component is food waste (53%) which is sent to composting center and/or refuse-derived fuel (RDF) plant. This is followed by garden waste (11%) and plastic film (6%). Food waste and garden waste make up the largest portion due to its high generation. This indicates a typical waste generation trend in many developed country where these organic components are sent for biological treatment or energy production (Al-Salem, 2008; Demirbas, 2004; Zabaniotou and Kassidi, 2003; World Bank, 1999). Figure 4.4 illustrates the recycled components as generated by SWPlan (for Selangor).

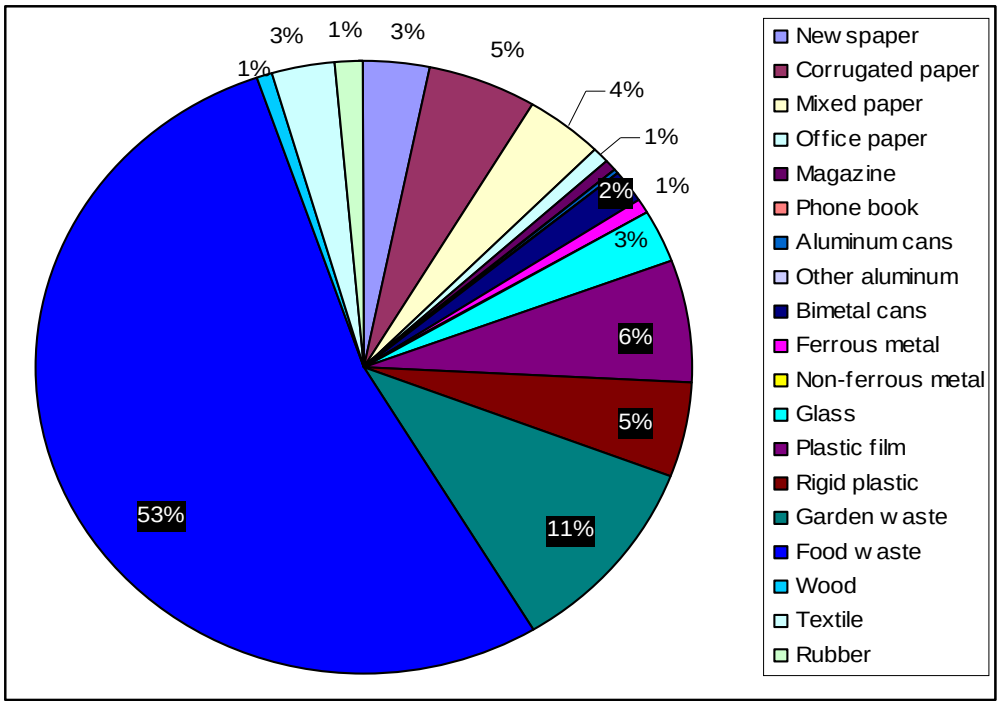

Figure 4.4: Percentage of recycled materials computed using SWPlan after the implementation of the 2020 waste management target in Selangor.

Detailed on tonnage of recyclable generated, source reduced and recyclables recovered are depicted in Appendix 4.5. Collection cost for recyclables is shown in Table 4.12.

Table 4.12: Recyclables collection of 2020 target, generated using SWPlan for Selangor.

	Recyclables collection
Commercial on-site collection (tonnes per annum)	19,463
Cost commercial on-site (per annum)	RM596,971
Drop-off center collection (per annum)	228,854
Cost drop-off center (per annum)	RM2,732,541
Total collection cost for recyclales (per annum)	RM3,329,512
Collection cost/tonne	RM13

The tonnage at commercial on-site recycling center was relatively lower than that of drop-off center. This is expected to happen due to the preference of the public in discarding their recyclables at drop-off center since it is more convenient. Findings had indicated that the majority of the public would be encouraged to recycle if more convenient facilities are provided (Fauziah and Agamuthu, 2007). The total collection cost for recyclables is RM3.3 million (Table 4.12) while the transportation cost for rejects amounted to RM12,327 (Appendix 4.5). Revenue earned from the recyclables is approximately RM24 per tonne.

The largest net revenue is obtained from rigid plastic at RM91 per tonne (Table 4.13). This is due to the high market price for plastic, as a result of high petroleum price in the world market. Therefore, this would encourage more rigid plastic to be separated from the waste stream and ended in the recycling components. The second highest type of recyclables is corrugated paper with net recycling revenue of RM66 per tonne. The high rate and more demand for recycled paper encouraged the recycling of this material beside the fact that the material is also utilized in various goods manufacturing such as incense-making. The total transportation cost of recyclables in Selangor is more than RM1.5

million (Table 4.13) mainly to transport the rejects and products away from the collection center. Table 4.13 depicts end market for the recyclables, as generated by SWPlan.

Table 4.13: Annual revenues from recyclable at 22% recycling rate, as generated by SWPlan for Selangor.

Recyclable items	Tonnes of recyclable	Gross revenue/tonne	Transportation cost	Net revenue per tonne
Newspaper	8,351	RM50	RM75,497	RM41
Corrugated paper	12,628	RM75	RM114,154	RM66
Mixed paper	9,700	RM12	RM87,691	RM3
Office paper	2,583	RM30	RM23,350	RM21
Magazine	976	RM20	RM8,821	RM11
Phone book	344	RM20	RM3,113	RM11
Aluminum cans	488	RM40	RM4,410	RM31
Other aluminum	258	RM30	RM2,335	RM21
Bimetal cans	3,702	RM50	RM33,468	RM41
Ferrous metal	2,066	RM50	RM18,680	RM41
Non-ferrous metal	RM0	RM0	RM0	-
Glass	7,347	RM15	RM66,417	RM6
Plastic film	15,354	RM25	RM138,801	RM16
Rigid plastic	12,369	RM100	RM111,819	RM91
Garden waste	6,555	RM20	RM61,244	RM10
Food waste	65,592	RM20	RM642,801	RM10
Wood	2,568	RM30	RM30,043	RM18
Textile	7,404	RM30	RM86,631	RM18
Rubber	3,530	RM30	RM41,301	RM18
Total	161,817	RM34	RM1,553,574	RM24

Unlike other recyclables, the available end market for food waste and garden waste is more than one i.e. recycling for composting and/ or RDF conversion. This resulted with the generation of addition revenue as shown in Table 4.14.

Table 4.14: Revenue from second end market for food waste and garden waste as generated by SWPlan for Selangor as targeted in 2020 waste management proposal.

Waste types	Tonnes	Gross revenue/tonne	Transportation cost	Net revenue/tonne
Food	65,592	RM30	RM767,425	RM18
Garden	6,555	RM30	RM76,699	RM18

The recycling activities will help to generate side-income for waste managers to cater the total waste management cost. Figure 4.5 compares the cost per tonne by diferrent management methods as computed by SWPlan (for Selangor).

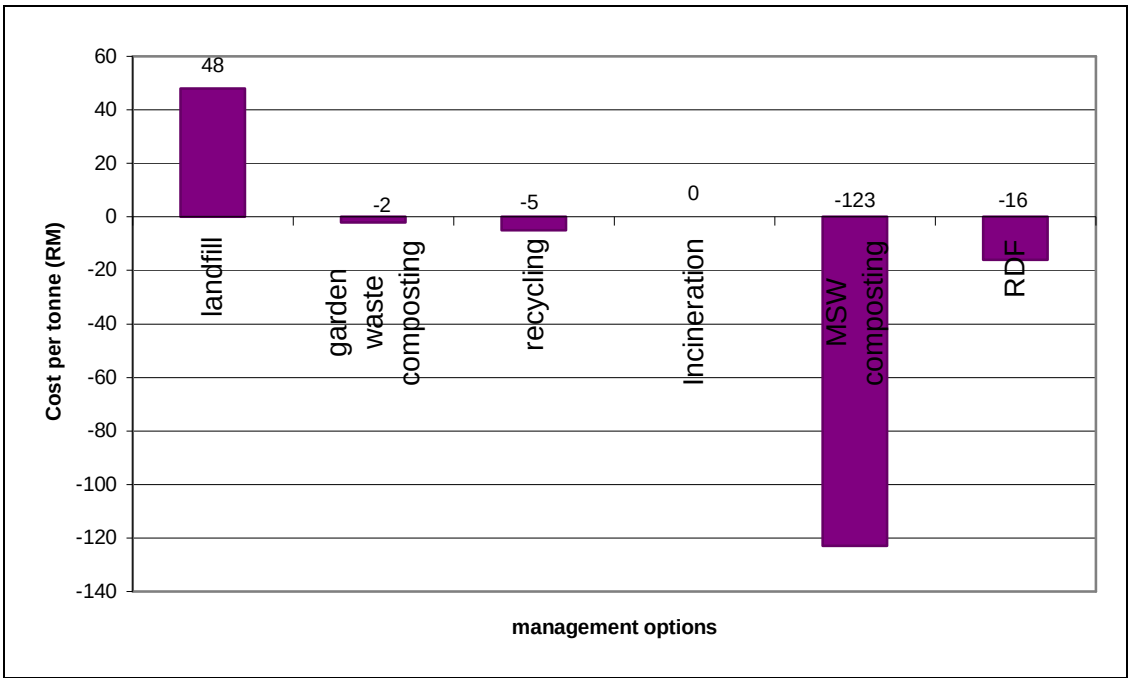

Figure 4.5: Cost per tonne associated with the management options as targeted in 2020. waste management plan, derived by SWPlan for Selangor.

Landfill has the highest cost at RM48 per tonne while the other management options indicated negative value or in other word revenue generation ranging from RM2 to RM123 for compost output. Appendix 4.5 illustrates the computations for detail tonnage

and costing for individual commodities as generated by SWPlan for Selangor in 2020. The capital and operating costs calculated varies greatly with different waste management options. The largest cost is incurred for landfill at RM100 million with annual debt service cost at RM10million. On the other hand the total facility and annual debt service cost is only RM0.2million and RM26,899, respectively. The annual operating cost for landfill and recycling center is RM11million and RM0.1million, respectively. This indicates the need for urgent changes in current waste management to divert from landfill disposal in order to reduce cost for landfilling service as well as promoting recycling. Capital and operating cost for the various management options is shown in Table 4.15.

Table 4.15: Capital and operating costs for different waste management options for Selangor as generated by SWPlan using the target proposed in 2020 waste management plan.

	Annual operation cost	Transportation cost (products and rejects) (per annum)	Gross cost (per annum)	Revenue (per annum)	Net cost per tonne
Landfill	RM11,221,691	RM0	RM21,491,288	RM0	RM48
Garden waste composting	RM131,769	RM142,234	RM274,003	RM327,774	RM-2
Recyclables processing	RM3,995,340	RM2,267,791	RM6,290,030	RM7,316,278	RM-5
MSW composting	RM4,856,688	RM3,492,930	RM8,349,619	RM46,138,540	RM-123
RDF	RM5,116,544	RM5,935,191	RM11,051,734	RM16,202,388	RM-16

Based on calculations using SWPlan application, the lowest cost is for MSW composting which generates the highest revenue. Landfill on the other hand is the most expensive

option to manage waste in Selangor. Findings indicated that the cost of disposal may be reduced with the implementation of other waste management options besides landfilling.

MSW composting may generate revenue of RM46million annually and reduce the cost of landfilling organic wastes. Though the market for compost was absent initially, current trend see more demand from farmer to replace in-organic fertilizer with compost (The Compost People, 2007). However, quality assurance is highly regarded that compost produced should maintain the essential nutrient contents.

SWPlan also indicated the viability of RDF conversion. The market for RDF pallets is expanding where the pilot-plant in Semenyih, Malaysia indicated positive response from various potential buyers such as cement manufacturing industries and the main Malaysian energy provider, Tenaga Nasional Berhad (Energy Recycle, 2010). RDF conversion creates revenue of as much as RM 16million annually. However, the software does not include the fluctuation of market prices. The software also failed to identify the possibility of unpredictable factors such as changes in policy and others. Therefore it is essential that all factors that affect the outcome should be included in generating a more accurate simulation scenario

4.5 Conclusions

SWPlan indicates that current waste management practice in Selangor did not generate any profit but exhausting the income of the waste managers (RM11million). The best management of waste in Selangor is the integrated system with MSW composting, RDF conversion and recycling, which not only reduced the waste management cost but also generated revenue from the marketable products. The incorporation of the MSW management based on the 2020 government's target would generate an income of more than RM62million per year.