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SWPlan Software Application for Malaysian Municipal Solid Waste Management

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ABSTRACT Among the biggest and most serious issues faced by a nation due to the impacts of urbanization and population explosion is the rate of waste generation. Per capita generation in Peninsular Malaysia is approximately 1.2 kg of municipal solid waste (MSW) everyday which amounts to 18,000 tonnes. Application of various tools to determine the efficiency of a system has been very helpful in minimizing costs and optimizing a desired system. This study was conducted to design an integrated solid waste management system and to determine the best integrated technology in terms of efficiency, cost and performance. SWPlan software was utilized to determine the appropriate waste management approaches including waste reduction, recycling, composting, waste-to-energy conversion, landfill disposal and others. The software was able to determine the capital operating cost and management costs, by taking into consideration the possible revenues from alternate options of waste disposal. Among the options which were examined included refuse derived fuel (RDF) conversion, recycling activities and other by-products from waste treatment options such as composting. In order to evaluate the potentials of SWPlan, information on population density, waste composition and amount were defined according to data obtained from waste management studies conducted earlier. Results indicated that waste generated by communities in Selangor in particular and Malaysians in general composed of a high percentage of organic waste, accounting for approximately 46% of the total tonnage. The option of composting, including yard waste composting and MSW composting were derived from the software application as it was found to offer the best system with the consideration of cost and energy efficiency. Findings also indicated the possibility of implementing RDF conversion to divert the waste stream which not only reduced the disposal cost but also generated significant amounts of revenue for waste managers. The other viable application is recycling. The application of SWPlan to MSW management in Malaysia optimized the economical aspects of the management and would reduce the existing environmental impacts due to improper waste disposal system currently practiced in the country.

ABSTRAK Antara isu yang paling rumit dan serius yang dihadapi oleh sesebuah negara yang berpunca dari kesan perbandaran dan pertambahan populasi adalah kadar penghasilan sisa. Penghasilan sisa pepejal munisipal (SPM) per capita di Semenanjung Malaysia mencecah hampir 1.2 kg setiap hari, menjadikan jumlahnya mencapai 18,000 tan. Penggunaan pelbagai alatan untuk menentukan keberkesanan sesuatu sistem amat penting dalam meminimalkan kos dan mengoptimalkan satu sistem yang dikehendaki. Kajian ini adalah untuk mereka satu sistem pengurusan sisa bersepadu dan untuk menentukan teknologi bersepadu yang terbaik dari segi efisiensi, kos dan aplikasi. SWplan digunakan untuk menentukan pendekatan pengurusan sisa yang sesuai termasuk pengurangan sisa, kitar semula, pengkomposan, penukaran sisa kepada tenaga, pelupusan di tapak pelupusan dan lain-lain. Perisian ini boleh menentukan kos modal operasi dan kos pengurusan dengan mengambilkira keuntungan yang mungkin dari pilihan pelupusan sisa alternatif. Antara pilihan yang diuji termasuklah penukaran kepada bahan bakar dari sisa atau "refuse derived fuel (RDF)", aktiviti kitar semula dan lain-lain produk dari opsyen-opsyen rawatan sisa seperti pengkomposan. Untuk menilai potensi SWPlan, informasi berkaitan ketumpatan populasi, komposisi dan jumlah sisa dimasukkan berdasarkan data yang diperolehi dari kajian pengurusan sisa sebelum ini. Keputusan menunjukkan bahawa sisa yang dihasilkan oleh komuniti di Selangor secara khusus dan rakyat Malaysia secara amnya mengandungi peratusan sisa organik yang tinggi sehingga 46% dari jumlah sisa sebenar. Pilihan pengkomposan termasuklah pengkomposan sisa kebun dan pengkomposan SPM diperolehi dari pengaplikasian perisian. Didapati ia menjadi sistem yang

terbaik dengan mengambilkira kos dan penggunaan tenaga. Keputusan juga menunjukkan kemungkinan perlaksanaan penukaran RDF untuk mengurangkan kos pelupusan sisa dan memberikan pulangan nilai kepada pengurus-pengurus sisa. Kitar semula juga adalah satu aplikasi yang sesuai. Penggunaan SWPlan kepada pengurusan SPM di Malaysia mengoptimalkan aspek ekonomi pengurusan dan mengurangkan kesan alam sekitar yang wujud akibat sistem pengurusan sisa yang tidak sempurna yang di amalkan di negara ini.

(SWPlan, Waste Management, Malaysia, RDF, Composting, Recycling)

INTRODUCTION

Advancement in technology experienced globally has enhanced the improvement in the quality of life of a society. The rapid development in technology had created a more pleasant environment to live in [1]. Findings indicate that the world's urban cities, covering approximately 2% of the land surface, utilized 75% of the world's resources [2]. The rate of resource utilization throughout the globe had exceeded the predicted rate with current increment at 2% until 2020 [3]. Most developed nations had experienced this event and benefited from it. Others, particularly the less developed countries, also experienced rapid development and their environment had to suffer the impacts of urbanization. Most countries, especially the developing and under developed countries were not able to cope with the rapid urbanization due to lack of infrastructure, proper planning and technologies. Among the biggest impact of rapid urbanization is the increase in waste generation.

The Asian region comprises of most of the developing countries where rapid progressive economical activities are taking place. The higher the rate of development for a nation, the higher the generation of waste [1, 4, 5, 6]. 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 sectors stand much higher than the environmental concern. Various detrimental effects to the environment are faced by these nations due to the lack of proper planning and unavailability of appropriate technologies. Malaysia spends approximately \$26.32 million (RM1 billion) every year to manage the annual waste increment rate at 3% [4]. In the state of Selangor, the generation of 3000 tonnes of MSW in 1997 is projected to

increase by 6.2% to 3100 tonnes in 2017 [4]. 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 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 [7, 8, 9]. Skordilis [10] 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 [11]. These tools manage to enhance best decision-making in waste management. It is also being practiced throughout the world to evaluate existing waste management in a country [12]. The tools allow simulation of scenarios with the consideration of the affecting factors. SWPlan is one of the planning tools utilized by solid waste management professionals which compares the cost of MSW management options. It evaluates existing waste management systems that incorporates all solid waste flows from the source to its final destination. It also has the capabilities to simulate different waste management systems and design an integrated system. This software can be applied to identify an integrated solid waste management system at the most effective cost. This study was conducted to design the most cost-effective MSW management system with the application of SWPlan within a selected vicinity in Selangor, Malaysia.

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MATERIALS AND METHODS

Waste composition studies were conducted at nine landfills where the waste received by these

landfills were analysed. Types of landfills involved in this study include urban, sub-urban and rural landfills throughout Selangor as listed in Table 1.

Table 1. Landfill types and the average tonnage of waste daily

LANDFILL TYPE	LANDFILL STUDIED	DAILY AVERAGE TONNAGE OF WASTE
Urban	Sungai Kembong	500
	Kundang	300
Sub-urban	Sungai Sedu	200
	Ampar Tenang	100
	Kerling	150
	Kampung Hang Tuah	100
Rural	Panchang Bedena	60
	Hulu Yam Bharu	50
	Bukit Beruntung	80

Randomly selected lorries downloaded their contents onto a specified area where the wastes were divided into four portions. The wastes were then sorted out according to their categories of putrescible 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. The waste was then weighed and the percentage of each category determined.

The data obtained from the waste composition studies from the nine landfills were computed to derive the average value for Selangor waste composition. The values obtained were applied into SWPlan accordingly. Besides the values of waste composition of required waste categories, the other information including population, percentages of the sources of waste and cost of waste collection were also computed in the SWPlan application. The best integrated waste management system was derived through the identification of waste management options from the software application. Formulations were generated automatically with the insertion of data on cost and management.

RESULTS AND DISCUSSION

From the waste composition studies, Selangor, as one of the fastest developing states in Malaysia, displays the waste generation of an urban area with a high percentage of paper (15%) and plastics (14%). The application of data using SWPlan generates a waste composition chart indicating the percentage and daily tonnage of each waste group as featured in Figure 1.

Current practice of MSW management focuses mainly on waste disposal as approximately 95% of the total wastes collected were sent for landfilling. A very small percentage (5%) was recycled. The application of SWPlan indicated the possibility of diverting the waste stream from its final end in landfills to other benefiting options. Figure 1 displays the high percentage of materials which are recoverable from the MSW stream such as food waste for composting option. Paper waste i.e. newspaper, corrugated paper, office paper and others, aluminium based waste, glass waste and certain types of plastics are recyclable while others can be converted into refuse-derived fuel resources.

Findings based on the SWPlan application indicated that the cost of disposal may be reduced with the implementation of RDF conversion option. Table 2 summarizes the cost and revenue from composting, RDF conversion and recycling options.

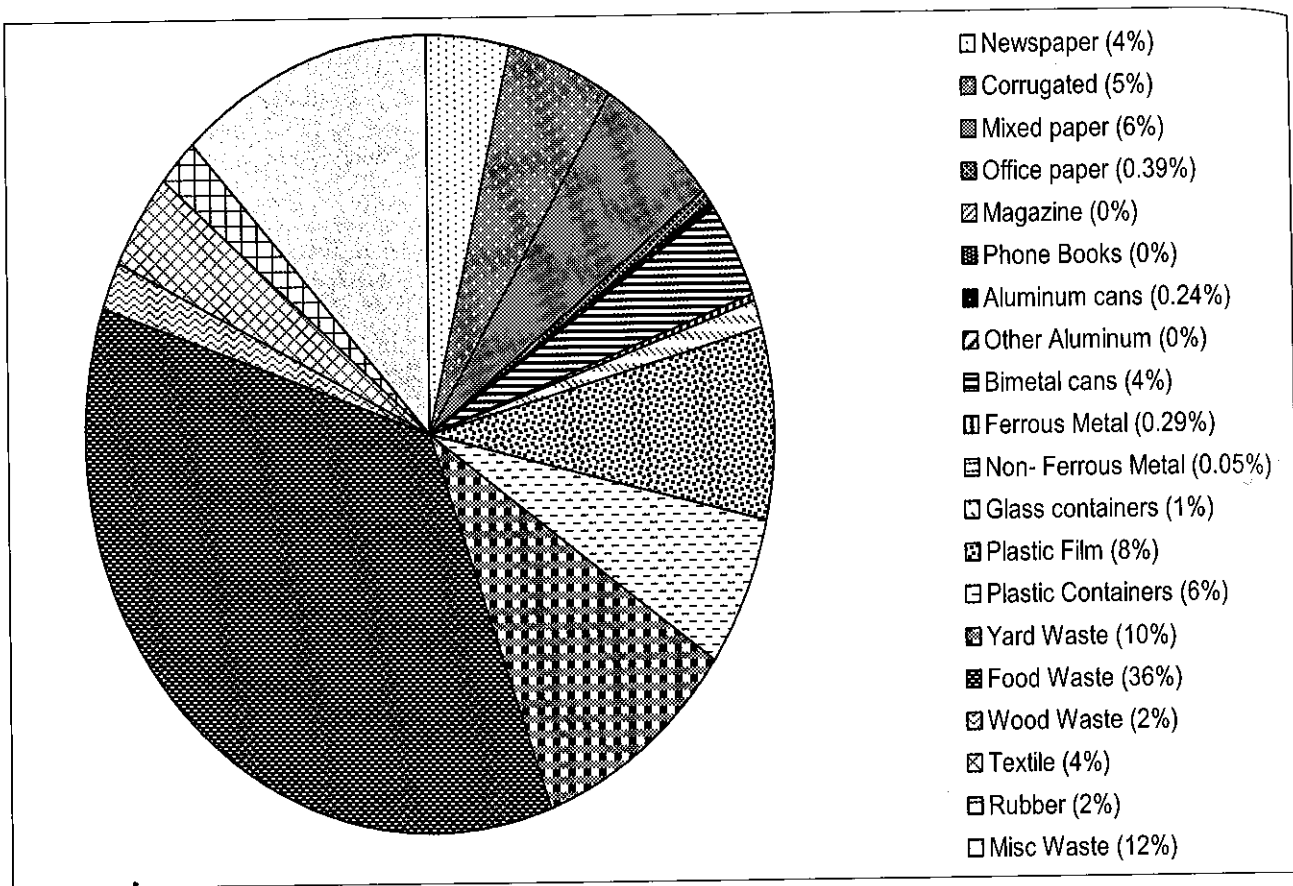


Figure 1. MSW composition- daily generation in Selangor State

Table 2. Simulated Costs of Alternative Options and Income from SWPlan

ISSUES		COMPOSTING	RDF CONVERSION	RECYCLING
Material involved (%)	Maximum	62%	89%	27%
	Minimum	36%	29%	20%
Changes in collection cost		Insignificant	Increase 30%	Decrease 45%
Disposal cost reduced	Maximum	US\$ 16,632	US\$ 23,875	US\$ 8,877
	Minimum	US\$ 9,657	US\$ 7,780	US\$ 6,444
Net Products (tonnes)	Maximum	1,020	2,000	843
	Minimum	578	741	612
Gross Revenues	Maximum	US\$ 536, 520	US\$ 26,320	US\$ 8,877
	Minimum	US\$ 304,028	US\$ 9,751	US\$ 6,444

Recoverable materials accounted for approximately 56% of the total waste generated which could be grouped further into organic and non-organic materials. At least 20% or approximately 680 tonnes daily can be recycled while the remaining can be composted. The results were found to be similar to the previous

findings indicating organic waste as the highest portion in the MSW stream [4, 5].

Composting option generates larger revenue involving at least 36% of the total tonnage. Besides being a more manageable system, composting of MSW produced high quality composts which is marketable in landscaping and

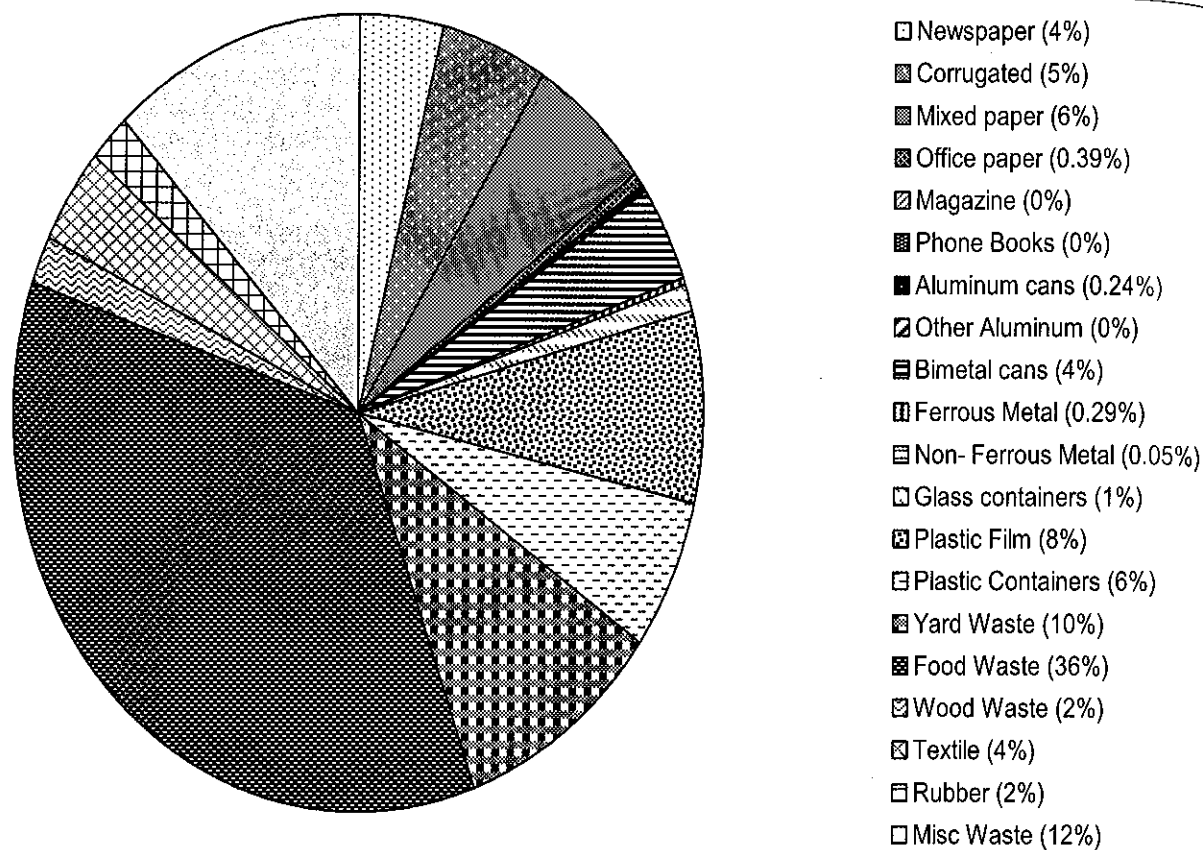


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Composting option generates larger revenue involving at least 36% of the total tonnage. Besides being a more manageable system, composting of MSW produced high quality composts which is marketable in landscaping and

other agricultural sectors. Application of compost can reduce substantial cost in waste disposal [4, 6]. Composting will utilize at least 36% with 2% rejects or at least 1,224 tonnes of putrescible waste and 170 tonnes of rejects. Composting may generate gross revenue of \$304,028 - \$536,520 (approximately RM1.2 million – RM 2.0 million) as indicated in Table 2.

As for the recycling program, the waste collection cost may be reduced by 45%. This is possible with the introduction of curb-side recycling system which will cut the collection cost by approximately 45%. However, the revenue which can be obtained from the implementation of recycling option may fluctuate with the market price of recyclables such as metal, papers and others with highest revenue to reach approximately \$9,000 (RM 34,200).

SWPlan also indicated the viability of RDF conversion. The collection cost incurred by the waste managers may not be reduced but may experience some slight increase due to extra transportation cost of commuting wastes to RDF plants. However, the disposal cost of the diverted portion can be reduced significantly besides the generation of marketable RDF pellets. At least 29% or approximately 1,000 tonnes of waste can be processed into RDF pellet to generate approximately 741 tonnes of products with 5% rejects. Average disposal cost saved would be approximately \$15,000 (RM 57,000) per day while the net revenue generated from RDF pellets is estimated to be approximately \$9,750 (RM 37,000) per day. RDF conversion of the combustible MSW portion can reduce at least 30% of waste disposal costs while generating revenue from RDF pellets commercialization. The software is applicable to simulate and design system suitable to be applied at a specific scenario, similar to other environmental software application [8, 9, 12]. 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.

CONCLUSION

Findings indicated that the best management of waste in Selangor is the integration of options namely composting, RDF conversion and

recycling, which not only reduced the waste management cost but also generated revenue from the marketable products. The highest gross profit, approximately \$ 300,000 - \$ 540,000 (RM 1.2 million to RM 2.0 million) can be generated from composting the putrescible waste accounting 36 - 62% of the total waste stream. Lower gross profit obtained from recycling option as compared to that of RDF conversion can be buffered with the 45% reduction in waste collection cost. This indicated that the selection of either RDF conversion or the recycling option may present similar level of revenues.

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