DECISION SCIENCES INSTITUTE

Selection of solid waste management program for the University of Houston – Clear Lake using analytic hierarchy process

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ABSTRACT

As a university grows, there is an increase in waste generated. Waste improperly disposed of could lead to health hazards for both humans and other lives and disrupt campus ecosystem. This paper studies the different kinds of Solid Waste Management (SWM) programs that are currently in use. The objective of this paper is to identify the best SWM practice suitable for the University of Houston Clear Lake (UHCL). To evaluate the different SWM practices, the Analytic Hierarchy Process (AHP) is used. The results show that waste reduction is the most appropriate SWM program for UHCL.

KEYWORDS: Solid waste management (SWM), Multi-criteria decision analysis (MCDA), Analytic hierarchy process (AHP)

INTRODUCTION

The world population is increasing at a steady rate. As the population continues to grow, so are the issues that arise with it. Some of the significant environmental challenges that we currently face are pollution, global warming, and waste management (WM). Municipal Solid Waste (MSW) is waste that consists of everyday items such as paper, clothing, bottles, cans, grass clippings, food scraps, product packaging, batteries, paint, and appliances (Farrell and Jones, 2009). WM can be defined as all the activities that are involved in managing waste. Since solid waste co generated in large quantities in industry, the responsible companies have to develop effective strategies to collect and dispose of this waste efficiently. Therefore, it is critical for the solid waste management team to accurately predict the quantities of waste produced for better WM (Chang and Lin, 1997).

Environmental sustainability is one of the most important goals for communities of all kinds. Educational institutions usually occupy significant amount of land with a large population living there. They could play important roles in protecting the environment and effectively managing natural resources. They consume raw material and energy as a part of their day-to-day activities (Kaplowitz et al. 2009). Therefore, they may be considered as communities that affect the environment in both direct and indirect ways (Alshuwaikhat and Abubakar, 2008).

Solid waste follows a WM hierarchy, which is the most widely accepted guide to make the best use of resources. It lays out the sequence of WM procedures in the most to least preferable order, i.e., reduction, reuse, recycling, energy recovery and safe disposal. Reduction could be any activity that reduces the amount of waste created.

Reuse puts unwanted goods to use, either in their existing form or by making some basic modifications. Recycling involves converting waste into something new, which can be used again. Energy recovery converts waste that is non-recyclable into energy such as fuel, power or heat. The last step in the hierarchy is the disposal of the waste that remains after all these stages. The waste goes to a landfill, where it is buried. It is the least preferred method of waste disposal since there is no form of energy that can be recovered from this stage.

Extensive research has been conducted on solving different WM problems using various methods. One of the frequently used methods is the multi-criteria decision analysis (MCDA) method. It uses a set of criteria to solve problems that involve decision making (Kahraman, 2008). One of the earliest studies was conducted by Merkhofer and Keeney (1987) to determine a site for nuclear waste disposal by employing MCDA. Hokkanen and Salmon (1994, 1997) conducted a study on the selection of a solid waste management (SWM) system. They employed the ELECTRE III decision aid method and MCDA.

The remainder of the paper is organized as follows. The section on literature review discusses SWM and AHP. The section on research methodology and results describes the methods in details and presents the findings of this paper. Finally, the section on conclusion draws some conclusions.

LITERATURE REVIEW

SWM can be defined as a set of activities that contributes to the reduction of the bulk of solid waste produced within an organization. Some of the activities include reduction of the sources, recycling and reuse of material, and composting. Waste is generated from different sources. The major contributors are households, business and commercial establishments, and institutions. The waste that is generated from households is considered municipal solid waste. It usually consists of everyday items and food waste, used papers and bottles, clothing, batteries, etc. (Haghi, 2010). It is impossible for humankind to stop creating waste as long as the alteration of chemical environment continues (Prasanna 2001). Even though the problem of waste disposal has been in existence since prehistoric times (Pitchel, 2005), waste has become toxic and reached unmanageable levels only in the recent years.

Industrial civilization in the 21st century contributed to the increase in economic activities worldwide (Ayomoh et al. 2008). As a result, there was a significant increase in the population across the world, which directly contributed to the amount of waste generated (Ziyadat and Mott, 2005). The amount of solid waste generated from the household and industrial activities is directly proportional to the number of resources consumed. As a result, the health and wellbeing of humans were threatened (Frosch, 1996). Sangodoyin and Ipadeola (2000) noted that the progress made in the field of science and technology also contributed to the increase in the amount of toxic waste generated.

The environmental pressure from legal activities has been in existence for the last many years. It is difficult for the higher educational institutions to disregard the effect of their activities on the environment. One such activity is the generation of solid waste (de Vega et al. 2008). When an educational institution implement a suitable WM program, it helps its community to understand that the problems caused by poor SWM can be mitigated with the help of continuous and systematic procedures. By implementing such procedures, the educational institutions will set an example, influencing other neighboring communities to incorporate WM programs of their own.

There is a need for university campuses to perform an in-depth analysis of solid waste characterization because of the lack of information readily available on this subject. Campuses have the advantage of accommodating creative SWM procedures requiring the involvement of students to some extent. This helps the students gain an understanding of the best practices of SWM, which they can apply in their future working environments.

Identifying the nature of waste and studying how it can be utilized are critical to the strategy development and implementation of appropriate WM strategies. The statistical data that keeps track of the types and amount of waste generated, and the different WM procedures implemented by various educational institutions can be used as a source of information for future studies. It can also be used to identify best practices for implementing SWM plans within the context of educational institutions.

As observed by Armijo et al. (2003), WM programs have been in use by higher educational institutions for the last 20 years and significant efforts have been made to institutionalize it. Successful results have been observed by institutions which took the initiative of implementing waste reduction and recycling programs, and it is considered as one of the most favored environmental initiatives.

According to Allen (1999), WM programs have been institutionalized by 80% of the higher educational institutions in the United States. The basis for these programs is the study of waste characterization. Results from one study at Brown University shows that 45% of the different kinds of wastes generated in the university is recyclable. Based on an article published by the university in 2004, it had a WM program in place since 1972 and was recycling 31% of the waste generated. The University of Florida and Colorado State University are recycling 30% and 50% of their wastes, respectively. The University of Pennsylvania has a color code system for their waste, which simplifies the trash collection process. Regular trash is collected in white bags, recyclables are collected in blue bags and food waste in green bags. Regular trash is taken to landfills. The recyclable trash is collected by vendors to be sorted and recycled. The University of California at Berkeley has set specific goals to achieve campus sustainability. Some of their goals include reduction of greenhouse gas emissions, ensuring minimal consumption of energy and water when designing future projects, reducing fuel usage on campus, etc. Some of the goals have been accomplished, and the rest are yet to be achieved. Louisiana State University has incorporated a campus sustainability plan with activities that require community involvement. They recycle plastic, cardboard, paper, metal cans, glass, batteries, ink cartridges, etc. They also have roll-off lots where green debris, scrap metal, and concrete are brought to be reused. It is mandatory for all the higher educational institutions in the USA to have a waste reduction and recycle program in place (de Vega et al. 2008).

SWM problem is complex that needs to consider environmental, financial, technical and social aspects. There are few WM models that consider the social aspect before implementing a SWM program. Sustainable SWM systems need to be effective in preserving the environment, affordable and accepted by the society (Morrissey and Browne, 2002). For the SWM strategy to be more effective, the management must involve the public before making important decisions.

Multi-criteria decision analysis (MCDA) is a decision-making technique that has been developed to solve complicated problems involving several individual criteria, which are often conflicting in nature (Wilson, 2004). This method is more robust in solving problem involving more than one criteria than decision-making techniques designed to solve single-criterion problems. With this model, the decision makers could understand the problem thoroughly and choose the appropriate course of action from various perspectives.

Analytic hierarchy process (AHP) is one method of MCDA that helps decision makers address problems involving complex decisions (Saaty 1980). AHP addresses decision-making by identifying the important parts of a problem such as the criteria and alternatives and arranges them in a hierarchical structure. Pairwise comparisons are made between the criteria and alternatives to obtain their relative weights. With AHP, the decision makers can select the best alternative and provide a rational explanation.

RESEARCH METHODOLOGY AND RESULTS

In this paper, we apply AHP to find the most suitable SWM program for University of Houston Clear Lake (UHCL). The steps in implementing AHP is as follows:

- Identifying the problem and determining the goal
- Identifying the decision criteria
- Calculating relative weights of the
    a. Conducting pairwise comparisons
    b. Computing relative weights
    c. Evaluate the consistency of pairwise comparisons

  Compare the alternatives

The goal of AHP is to identify the best SWM program for UHCL by studying various SWM procedures in use and understand their application for the current scenario. Once the goal is determined, the next step is to identify the decision criteria. These criteria should specify a complete set of objectives that covers all the relevant concerns. When considering SWM from the perspective of a higher educational institution, it is difficult to implement a single SWM program because the kind of waste generated is diverse. There is a specific type of disposal method for a specific type of waste.

Based on the alternatives, six decision criteria have been identified that cover all the important aspects related to different methods of solid waste disposal.

They are explained as follows:

a Environmental impact:

The most important concern when it comes to the method of solid waste disposal is its impact on the environment. Some SWM procedures have a harmful effect on the environment and should not be implemented unless there is no other alternative. Therefore, when considering a SWM program, decision makers should conduct a thorough study on the environmental impacts before implementing it.

b Operating cost:

The next important criterion is the operating cost involved in implementing a specific SWM program. For example, some procedures such as incineration require expensive equipment. SWM department at any educational institution would have a specific budget allocated. The decision makers should ensure that the SWM program is financially viable while serving its purpose.

c Resources:

Resources in this context are referring to the number of people that are required for a specific disposal method. It is an important criterion because the labor cost needs to be considered as well.

d Complexity:

The complexity of implementing a disposal method is the next criterion. Implementing a SWM strategy for a university is to achieve some level of involvement from the community. If the procedure specifically requires trained workers, it is difficult to involve the students, educating them the importance of SWM and providing trainings on required skills.

e Laws and regulations:

Some SWM programs have specific laws laid by the government associated with them to be incorporated. It is mandatory to know the rules before starting any work associated with that procedure. It is an important criterion because it involves laws and failure to follow them might cause the university legal troubles.

f Time:

This criterion refers to the time that it takes in completing a specific SWM process. If it is a simpler process with effective results, it will be easier to implement and accepted by the university.

The alternatives considered in this research paper are:

a. Waste reduction
b. Reduce and recycle
c. Incineration
d. Composting, and
e. Landfill.

Once the criteria and alternatives are identified, the next step is to draw the hierarchy, which is shown in Figure 1. The relative weights of criteria and alternatives are calculated using Saaty's fundamental scale of importance as shown in Table 1. Tables 2 and 3 show the relative weights of criteria and alternatives, which are calculated using Saaty's fundamental scale of importance.

Figure 1: The AHP hierarchy tree

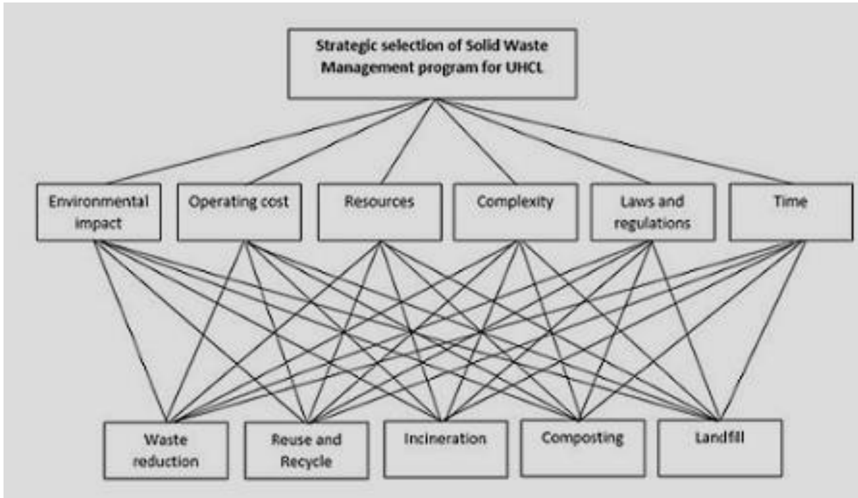

Table 1: Rating Scales for Pairwise Comparisons (Saaty 1980)

Relative Importance	Value
Equal importance/quality	1
Somewhat more important/better	3
Definitely more important/better	5
Much more important/better	7
Very much more important/better	9

Table 2: Relative Weights of Criteria

	Environmental impact	Operating Cost	Resources	Complexity	Laws and regulations	Time	Priority Vector	Product
Environmental impact	0.4778157	0.653950954	0.25	0.403361345	0.403846154	0.31579	0.4174606	2.1650788
Operating Cost	0.119453925	0.163487738	0.25	0.403361345	0.173076923	0.23684	0.2243703	1.639055
Resources	0.09556314	0.032697548	0.05	0.033613445	0.019230769	0.02632	0.0429034	0.2763582
Complexity	0.119453925	0.040871935	0.15	0.100840336	0.173076923	0.31579	0.1500054	1.0351514
Laws and regulations	0.068259386	0.054495913	0.15	0.033613445	0.057692308	0.02632	0.0650628	0.4116014
Time	0.119453925	0.054495913	0.15	0.025210084	0.173076923	0.07895	0.1001974	0.6407528

Table 3: Relative Weight of Each Alternative against Each of the Criteria

	Environmental impact	Operating cost	Resources	Complexity	Laws and regulations	Time
Waste reduction	0.538082316	0.05343978	0.04996866	0.051425001	0.094121059	0.5117694
Incineration	0.229955595	0.093259455	0.144769689	0.084256738	0.052345651	0.2072335
Reuse & Recycle	0.114105682	0.259087003	0.461182648	0.519509887	0.406541193	0.1380543
Landfill	0.044320255	0.155986417	0.249038624	0.187051088	0.263743351	0.0918288
Composting	0.073536152	0.438227345	0.095040379	0.157757286	0.183248746	0.051114

Once the AHP is completed, the preference scores for alternatives are obtained as in Table 4. These values are obtained by multiplying the priority vectors of the alternatives with respect to criteria with the criteria ranking. From Table 3, it can be understood that waste reduction is the best SWM strategy that is suitable for UHCL based on the AHP. Table 5 shows the overall consistency ratios of the criteria and the alternatives.

Table 4: Aggregated Weights or Global Preference Scores of Alternatives

Alternatives	Scores
Waste reduction	0.303878057
Incineration	0.159942152
Reuse & Recycle	0.243765084
Landfill	0.118604863
Composting	0.173809843

Table 5: Consistency Ratios of the Pairwise Comparisons for Criteria and Alternatives

Set of wts	1	0.417460604	0.224370339	0.042903449	0.150005432	0.0650628	0.1001974
CI	0.085157304	0.099337146	0.080739881	0.078664985	0.076444872	0.0890857	0.0958424
RI	1.24	1.12	1.12	1.12	1.12	1.12	1.12

Conclusion

It can be concluded that waste reduction is the most appropriate SWM strategy UHCL since it is affordable, environmentally safe and socially acceptable. The next best alternative is reuse and recycling, which also reduces the amount of waste generated and convert wastes to new products to be used for other purposes. Composting is advantageous for recycling organic waste but can be expensive. Incinerators are used to convert solid waste to fuel but require expensive equipment and skilled labor. It gives rise to harmful gasses, which cause air pollution. Some of the gasses emitted are harmful to living creatures. The landfill is the least preferred method as it takes years to decompose the waste. Unfortunately, it is the most widely used method. This method of waste disposal also gives rise to harmful gasses that contribute directly to global warming. It also contaminates ground water. The harmful effects of landfill can be reduced by sorting the waste so that they can be sent to other waste management processes such as recycling and incineration. The results of this study can be used by other educational institutions and universities to improve their existing SWM strategy and contribute to the environmental sustainability.

AHP method is the most suitable method for this study since it checks the consistency ratios of all the criteria and the alternatives to ensure a rational decision. It is also suitable because this method offers the flexibility to include more criteria if needed during the process of performing AHP. It also enables the decision makers to make modifications to improve the consistency of their pairwise comparisons.

After performing AHP, it can be understood that waste reduction is the most suitable SWM strategy that can be implemented at UHCL. The reason is because it reduces the production of waste and contributes to the sustainability of the campus and the environment. It is achieved by making small but significant changes to the everyday activities such as using the recyclable material as much as possible. It is beneficial because it reduces the amount of money that a university spends on waste management strategies. Those financial resources can be used for other significant purposes such as research and development. Implementing the waste reduction strategy helps create awareness among surrounding communities and improves the status of the university. It also helps reduce pollution and conserve the energy.

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