Review of Waste Management Models and Their Application

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Abstract

The purpose of this work is to review the types of models currently in use in the municipal waste management sector and highlight some of the main shortcomings of these models. Majority of the municipal waste models recognized in the literary work are decision aid models and, for the purposes of this research, they are divided into three categories: those based on the cost-benefit ratio analysis, those based on life cycle assessment and those based on multi-criteria decision-making. Current waste Management models which taken into consideration of the paper are related to the refinement of the assessment phases rather than addressing the decision making process itself. Likewise, for a waste administration model to be practical and sustainable, it should think about ecological, financial and social viewpoints, No model examined considered all three aspects together in applying the model.

Keywords: *Solid waste management models, CBA, LCA, MCDA.*

Classification-JEL : *E63, F18*

1. INTRODUCTION

The development of tools and methods to help decision-makers over Solid waste management systems (SWM) has been a traditional research topic in the waste management field in the past few decades. The objective of this paper is to study the models that are being used to support decision making in the area of municipal waste management and to identify some advantages and disadvantages of these models. A model is the representation of an object, system or idea in some form, other than that of reality itself(Qureshi et al., 1999). Most of the models recognized are decision support models, using a variety of methods and tools, such as life cycle analysis (LCA), risk assessment, cost-benefit analysis (CBA), environmental impact assessment (EIA), and multi-criteria decision making (MCDM), as part of the decision making process. After reviewing the literature related to models it can be assumed that all options and criteria on which decisions are to be made have already been identified and the most important task of the process is the actual evaluation of these alternatives using different tools and methods of SWM. The type of tool selected also depends on the decision being made and on the decision-makers (Zopounidis and Doumpos, 2002; Guitouni and Martel, 1998; EEA, 2003). Tools like these are an important part of the identified waste management models, but only a part, since the focus of this research is on the models for the management of urban waste and, therefore, goes beyond the tool used to help in the decision-making process. In some cases, the goal of the model is simple (optimize waste collection routes for vehicles), while in others it is more complex (evaluate alternative waste management strategies). For the purpose of this survey, only the most complex models for decision making in municipal waste management will be considered. Decisions relating to industrial, hazardous or liquid waste also go beyond the scope of this investigation.

2. A BRIEF REVIEW OF PAST FINDING ON WASTE MANAGEMENT MODEL

Modelling waste management is not a new idea. Gottinger (1988), MacDonald (1996a), Berger, Savard et al. offer a complete summary of the models developed in the 1970s, 1980s and early 1990s. (1999) and Tanskanen (2000) and among others, describe the dynamic mixed integer programming model of Baetz and Neebe (1994), a multi-period and multi-regional model developed by Everett and Modak (1996) and the static nonlinear programming model, MIMES / WASTE developed by Sundberg et al. (1994) These summary articles span a 12-year period and indicate the changes that occurred in the area of municipal waste management modelling during that period. Like Berger, Savard et al. (1999) and Tanskanen (2000) point out that the first solid waste management models were optimization models and addressed specific aspects of the problem, for example, the path of vehicles, Truitt et al. (1969) or location of the transfer station, Esmaili (1972). However, according to Berger et al. (1999), the first models had several shortcomings, such as having only one period of time, recyclable materials are rarely taken into account, having only one processing option for each type or having a single generation source. These limitations have the effect of making them unsuitable for long-term planning according to Sudhir et al. (1996). MacDonald (1996a) extends this, by noting that much of the work done in the 1970s '' has attempted to apply and refine various optimization and heuristic techniques to provide a more realistic representation of solid waste management practices. "

The models developed in the 80s have extended the system limits of previous and covered models of Municipal Solid Waste Management (MSWM) in the System-level; this means that the models have examined the relationship between each factor in the waste management system, instead of looking at each one in isolation (MacDonald, 1996b). In addition, the rise of computer literacy and availability in the late 1980s gave an opportunity to develop more sophisticated waste Management models. The main goal of the models developed in the 1980s was to minimize the costs of mixed waste management (Gottinger, 1988) and recycling has been included in some of them (Englehardt e Lund, 1990). While the main concerns of these the first models were generally inexpensive, some researchers recognized the social equity problems related to the installation site (Fuertes, 1974). Other researchers, for example, Motameni and Falcone (1990) observed influence people's attitudes, so they can change their behavior at the time of recycling. However, the inclusion of social problems like these was unusual.

Another feature of these previous models is that they were only concerned with treating waste once generated and the models did not include minimization or aspects of prevention. However, Boyle (1989) has noticed that “reducing the amount of waste it ultimately requires elimination at the point of generation is the most rational and cleaner means for solid waste management ". However, the terms of sustainable waste management or integrated waste management have not been used in any waste management model until this moment.

During the 90s, recycling and waste management methods were included in most of the models developed for the planning of municipal solid waste management (MSWM), such as those developed by Morris (1991), Smith and Baetz (1991), Chang and Wei (1999) and MacDonald (1996a). Even current models reflect a change in the policy in which waste is planned pushed by a landfill unit, a range of waste management techniques based on principle of integrated solid waste management (ISWM) (ERRA, 1999; Gabola, 1999; Kowalewski et al. al., 1999; Berger et al., 1999; Clift et al., 2000; EPIC and CSR, 2000). ISWM considers the whole range of waste streams to manage and see available waste management practices as options menu which to select the preferred option based on the specific site Environmental and economic considerations. More Recent models include the complete product life cycle. (Barton et al., 1996; Bjorklund et al., 1999; Warmer Bulletin, 2000; Finnveden, 1999; Powell, 2000; McDougall et al., 2001; Harrison et al., 2001; EPIC and CSR, 2000) with the aim of realizing an environmental impact assessment of systems, including all significant activities during its life cycle. Smith and Baetz's (1991) research also demonstrates that very little literature was available in the 1990s on costs in integrated waste management systems.

As described above, most of the waste management models consider the economic and environmental aspects, but a lot few consider social aspects. For waste management to be sustainable, it must be environmental friendly, effective, economically accessible and socially acceptable, Nilsson-Djerf and McDougall (2000), said "for a waste management system to be effective, must be accepted by the population. "This point is underlined by Petts (2000) who says that "Most Effective MSW management must be related to the premises environmental, economic and social priorities it must go beyond traditional consultative approaches that require the expert to write the solution, Promote public participation much more effectively and that involves the public before the key elections It has been done. Public opinions towards incinerators and landfills

[NIMBY, NOTE, LULU and BANANA (see appendix)] They are also factors in determining the waste management policy and this is reflected in more recent models. Berger et Alabama. (1999) acknowledges that improvement is needed for its optimization model developed for solid waste management planning, EUGENE, is "the addition" of various social and environmental indicators possibly use in multi-criteria analysis. Hummel's (2000) The goal of the model is to help determine how much it should cost to meet current recycling targets and set the optimal Recycling level that could be achieved. The difference between this model and similar ones is that demography, education and promotion (social factors) are an integral part of the model to be determined optimal levels

3. CURRENT MODELS OF WASTE MANAGEMENT

Rogers (2001) classifies the models into two categories: those who use optimization methods and those who use compromising methods While Rogers categorization focus on the evaluation of engineering projects, it is possible that it may also apply to waste management models. Tweaking the models assume that the different objectives of the plan or program can be expressed in a common denominator or measurement scale, whereby loss in a target can be measured directly against one gain in another. Optimization models include cost-benefit analysis and current worth valuation with the common scale of measure generally expressed in monetary terms. On the contrary, compromising methods assume that the manufacturer may have limited knowledge of the decision-making situation and rely on Simon Simon (1976) concept of "limited rationality". Guitouni e Martel (1998) also points out that the idea of the optimal solution is abandoned by the notion of 'Satisfaction of the decision-maker and that this is the start of the development of many MCDA methods. These methods are based on the principle that any workable solution must reflect a commitment of compromise among the various priorities while the discrepancies between actual results and suction levels are traded with each other for preference weights Each alternative is judged in relation to multiple priorities so that the desired alternative one that works comparatively well. A review of current waste management models shows that most can be classified into one of three categories: those based on cost-benefit analysis, those based on life cycle analysis and those based on a multi-criteria technique such as AHP or ELECTRE. A short discussion of each of these is given in the following paragraphs, followed by a discussion by its shortcomings. Note that not all the models fall into the previous categories, for example, the Models Chang and Wei (1999), Chang and Li (1997), Berger et al. (1999) and Sudhir et al. (1996) However, since they are more limited and they are not Direct relevance to current research will not be discussed further.

a) Cost-Benefit Analysis Models :

I) Description- This tool allows decision-makers to evaluate positives and the negative effects of a series of scenarios during translation all impacts to a common extent, usually money. This means that the impacts, which do not have a monetary value, like environmental impacts, must Estimate in monetary terms. There are several ways to do this, how to estimate the costs to avoid a negative effect (for example, the cost of controlling pollution in an incinerator) or to set the number of people willing to pay for environmental improvement. Social impacts can also be assessed in the same way. At the end of the analysis, the scenario with the maximum benefit and the minimum Cost, is the preferred scenario.

ii) Advantages And Limitations- The results are presented clearly, with all impacts are summarized in a monetary figure. It allows decision-makers to see which scenarios they are efficient in their use of resources. There is uncertainty in the estimate of the monetary value of various environmental aspects and/or Social impacts in monetary terms. This also increases ethical issues Price conditions may change during the useful life of the waste program, changing the preferred result (for example, changes in landfill costs may affect the amount of recycled waste).

As often happens, waste management scenarios are assessed strictly cost-benefit analysis framework. Environmental decision-making process generally implies on competiting interest groups, conflicting goals and different types of information and CBA is not an adequate decision aid for this decision (Carbone et al., 2000). In addition, the CBA approach allows you to improve a problem size (for example, costs), to compensate for the deterioration in another (for example, emissions), which is not sustainable approach to waste management. Finally the maximizing economic efficiency is usually the primary factor in a cost-benefit analysis on the expenses of environmental and social criteria, which once again not a sustainable approach to waste administration.

iii) Applications-Waste management plans developed in Ireland are based on cost-benefit analysis (for example, MCCK, 1998). Life cycle analysis data can be used to estimate the environment costs by applying an economic assessment to each environmental impact category. CBA can also be used for specific decisions, e.g. evaluation of packaging recycling and reuse systems (DRC e PIRA, 2003).

b) Models Based On Life Cycle Analysis :

i) Description- Life cycle assessment is a tool that studies the environment aspects and potential impacts along with a life of the product from the acquisition of the raw material production, final use and disposal (i.e. from cradle to serious) ISO 14040 (1997). While most of the life cycle studies comparative assessments of substitutable Products that offer similar functions (e.g. glass versus plastic for beverage containers) there has been recently trend towards the use of life cycle approaches in comparison of alternative production processes and this includes the use of LCA in the comparison of waste management (Berkhout and Howes strategies (1997). It also provides an overview of the product system, which can be combined with other evaluation tools, such as risk assessment to evaluate the product or life cycle service. According to McDougall et al. (2001), LCA offers a system map, which lays the foundation for a holistic approach and then compares those system maps for different options, both for different products of waste management systems. McDougall et al. (2001) link the concepts of Integrated waste management with that of life cycle Analysis. Integrated waste management systems is a combination of waste streams, collection, treatment and disposal methods, with the aim of achieving environmental benefits, economic optimization and social acceptability. The model developed by McDougall et al. (2001) called IWM-2 is based on both IWM and LCA concepts.

The life cycle assessment technique consists of four phases each of which is subject to International Standard: ISO 14041 (1998) ISO 14042 (2000) ISO 14043 (2000) for guidelines on its use.

ii) Advantages And Limitations- The use of LCA techniques is not necessarily make sure you can choose what the option is "Ecologically superior" because it cannot evaluate the real environmental effects of system of product, package or service. The true environmental effects of emissions and waste will depend on when, where and how they are released into the environment. Other tools like risk assessment, are able to predict the real environmental effects, but these techniques does not cover all environmental problems.

LCA is just a tool in the “environment administration toolbox "and should not be used in isolation to decide matters such as which waste management treatment option is preferred. EUROPEN, 1996; Finnveden and Ekvall, 1998).

A difficulty associated with the LCA is establishing where is the limit and the definition of functional unit (Ekvall, 1999). The results produced by the changes in the LCA (e.g. search for the same product) differ in practice (SEE, 2003).

LCAs are limited to environmental analysis. Although both Harrison et al. (2001) and Craighill and Powell (1996) extend the life cycle assessment methodology to incorporate an economic evaluation of the environmental impacts.

Addressing various environmental issues and impacts on human health, LCA can neither predict nor measure effects. It is a comparative tool that reduces the data to mass load based on simplification of assumptions and subjective judgments. "Significantly, LCA cannot cope with time type-dependent impacts relevant to the considerations "Petts (2000).

Models that take into account the entire life cycle of the product deciding on a waste management strategy is complexand very detailed. Consequently, potential users of these model, for example decision makers of Local Authorities often lack the necessary experience and data to use complex mathematical models. . . The most complex and confused. . . environmental data, other people will see financial data ”(Powell, 2000) which makes using the LCA approach a wasted exercise. Also, the use of LCA as a technique it has several limitations and usually not dealing with economic or social aspects (ISO 14040). Craighill and Powell (1996). However, expanding the LCA technique to include economic and social factors develop the Life Cycle Analysis (LCE) technique. It should be noted that these models only take into account the inventory phase of the life cycle analysis frame. The availability of a methodology for LCA assessment phase (ISO 14042), this should mean that the new LCA models will include both impacts and evaluation analysis. There are many supporters of the LCA approach including European (1996), McDougall, White et al. (2001), Daskalopoulos et al. (1998), Finnveden (1999), EPIC and CSR (2000) Ayalon et al. (2000).

iii) Applications- WISARD is an LCA package that the environment agency in England and Wales are using to help the locals waste management authority. WISARD and Others similar application called IWM-2 developed by McDougall et al. (2001) are life cycle inventory models, which gave an overview of a waste management system and "allow you to measure towards environmental goals and economic sustainability". These Models can be used in two ways, to compare future integrated waste management options or to be optimized existing options. While models only look at aspects of the life cycle inventory of waste management system (i.e. system inputs and outputs),it is recognized in McDougall's et al. (2001) IWM-2 That methodology for the impact assessment of the model must be include completeness. In the meantime, the WISARD and the IWM-2 models aim to offer both the environment and economic sustainability, but not to consider social aspects and therefore cannot be truly considered Sustainable waste management models. Powell (2000) uses the LCI model developed by White et al. (1995) (which is an earlier version of McDougall et al. (model described above), to study the factors influencing the use of LCI models. A similar but The most limited model is that developed by EPIC and CSR (2000) This model is also an LCI model for waste management systems, and was designed with the data contribution of City of London, Ontario, Canada and is used by municipalities across Canada. It is more limited because it does not consider all waste management available processes or all possible waste management charges It is meant to be a guide only and requires the entry of a number of other derived considerations such as social impact studies specific to the site and political factors to prescribe the "best" system.

c) Models Based On The Analysis of Multi-criteria Decisions :

I) Description- A brief history of the origins of multi-criteria evaluation methods are given by Bana E Costa et al. (1997). Despite the first vision of Benjamin Franklin on multi-criteria formulation of decision problems in 1772, when Franklin Structuring and evaluation used to solve problems with conflicting criteria and uncertainty, it wasn't until 1972 that the term multi-criteria decision making (MCDM) was introduced in management science in the United States. In Europe the term multi-criteria Decision analysis (MCDA) is more common for the the same thing. Over the past two decades, MCDA has developed as a separate discipline. A common feature of all the MCDA approaches is that taking several individual and often conflicting criteria taken into account in the a multidimensional shape leads to a more solid decision instead of optimizing a single dimension objective function (such as cost-benefit analysis). In addition, the multi-criteria approach helps decision makers to know the problem and the alternative courses of action from various points of view. Normal approach is to identify several alternatives (such as different waste management scenarios) which are therefore evaluated in terms of important criteria for the model or circumstances of the model being developed. The result is a ranking of alternatives. The criteria chosen in these types of models depend on objectives of the model and, therefore, could include Environmental impact assessment. A detailed description of the various MCDA techniques can be found in the models of Keeney and Raiffa (1976) (MAUT), Roy (1991) (ELECTRE), Brans et al. (1998) (PROMETHEE), Saaty (1980) (AHP), Jacquet-Lagreze and Siskos (1982) (UTA) and Zeleny (1982) (Multiobjective Improvement). More details of MCDA techniques can be found in Guitouni and Martel (1998), Bana E Costa et al. (1997), Rogers (2001), Salminen et al. (1998), Zopounidis and Doumpos (2002), and van Huylenbroeck (1995).

ii) Advantages And Limitations- Allows for a systematic approach to assessing policies options and helps understand the problem. It provide a mixture of quantitative and qualitative information. MCDA goes beyond the evaluation of purely economic consequences and allows non-economic criteria to be evaluated on equal terms. The preferences of various stakeholder groups with conflicts objectives (Bana E Costa et al., 1997, Qureshi et al., 1999). Multi-criteria techniques offer a level of flexibility and inclusion which is purely economic Models tend to be missing.

These methods don't produce the "best" solution, but a set of preferred solutions or a general Classification of all solutions. Solving this multi-criteria problem is therefore a commitment and it depends on the circumstances in which the A decision-making assistance process is underway. You need a personal judgment and experience. Some of the multi-criteria techniques are a lot cumbersome and difficult to manage (Beynon et al., 2000). The assignment of weights to each criterion is subjective. Changing the weights could result in Different result. When considering this model category for waste management options, the models identified in literature take waste into account once generated alone. Waste prevention, minimization of waste,or product design for the environment, which would eliminate the production of materials which cannot be reused, recycled or Generally biodegraded are not considered. The important point to keep in mind is that it is not just the inclusion of waste treatment techniques that determine whether it is sustainable or not, but if the program it is accepted by the people who have to use it. Finally, most of the waste management models identified worry about improvements in evaluation stages (for example, AHP four stage or weight assignments in ELECTRE) instead of addressing the decision making process itself and how contribution of all relevant stakeholders in the decision-making process can be improved. In other words, the The most important step to do it right is to formulate the problem in the first place, but most of the models have identified neglect this aspect, focus on reality, the MCDA technique itself.

iii) Applications- An analysis of multi-criteria models of waste management. shows that ELECTRE III is the most Commonly used method for waste management decisions in literature, p. Hokkanen and Salminen (1997) Courcelle et al. (1998) and Karagiannidis et Moussiopoulos (1998b). The AHP method is also used. in some applications, p. MacDonald (1996b), or a variant from AHP Takeda (2001) and Haastrup et al. (1998) This does not mean that none of the other methods identified by Guitouni and Martel (1998) it could not be applied to waste management problems. In fact, how are they doing? Huylenbroeck (1995) points out, both the PROMETHEE and WEST methods could be applied to waste management However, Salminen et al. (1998) compared three multi-criteria methods in context of environmental problems (ELECTRE III, PROMETHEE I and II (passing methods) and SMART (a simple multi-attribute scoring technique based on Keeney and Raiffa's Theory of Utility, 1976) and concluded that ELECTRE III was the most suitable as other methods have no superior characteristics when than that. While there is a well established PC implementation of the AHP method called Expert Choice, AHP The method is not widely used in waste management problems. Indeed, the MacDonald model (1996b) is the only one one found and also in this model, the use of AHP The method is only the final stage of a seven-stage process. (which also uses a geographic interface system, database and spreadsheets). In addition, Rogers and Bruen (1998a) suggests using methods to overcome preferences to the AHP method because the AHP method requires that all options are directly comparable to to each other, even when such comparisons are questionable due to the lack of adequate data. Rogers e Bruen (1998a) also considered ways of overcoming more capable than the AHP method of dealing with mixture of quantitative and qualitative information and this was one of the main factors in his choice of The winning approach. However, other authors like Lai et al. (2002) and Carlsson and Walden (1995), disagrees with this view and also shows that the The AHP method has been used successfully in group decision making doing. Whether or not the software is available The tools to help MCDA can be a reason to select a particular method of MCDA (Guitouni and Martel, 1998).

4. CONCLUSIONS

The development of MSW management models in the last few decades have been described in previous sections. The first solid waste management models were optimization and elaborate specific aspects of the problem. The latest models are compromising models, focusing on integrated waste management, with the concept that sustainability becomes essential for these models. Three main categories of models have been identified: cost profit analysis models, life cycle inventory models and multicriteria models. However, the models described have limits and none considered as full waste management cycle, from waste prevention to the final elimination. Most only care about the multi-criteria technique itself or compare the environmental aspects of waste management options (recycling, incineration and disposal). Moreover, although many models recognize it as a sustainable waste management model or, it must take into account environmental, economic and social aspects. None of the models examined took into account the three aspect together in the application of the model and No one has taken into account the intergenerational effects of proposed strategies. This is the affirmation of this research, that the non-involvement of the people who generate waste (i.e. the general public) is a serious shortcoming of these models and, therefore, it is argued that none of the models can be considered completely sustainable. Another weakness identified in the current models, is that no model identified takes into account participation all relevant stakeholders, i.e. the government, local authorities, technical experts Community. Due to these shortcomings, future research in this domain will carry two aspects of multi-criteria modeling and the concept of sustainable waste management together. To develop adequate decision making methodology for sustainable waste management it is necessary to involve all stakeholders of a community. This methodology will take into account development, evaluation and the implementation of a waste management strategy. Successful implementation of the strategy should not only be based on economic criteria or deviation rates discharge, but also on the inclusion of stakeholders, inter generational equity and satisfaction of social needs. This article has identified two important steps decision-making in the field of municipal waste management are the problem formulation and the active contribution of all relevant stakeholders in the decision-making processes.

Appendix

AHP	analytical hierarchy process
BANANA	Build absolutely nothing anywhere near Anything
CBA	Cost benefit Analysis
ELECTRE	Elimination and Choice Translating Reality (multicriteria method)
ERRA	European Recovery and Recycling Association
IWM	Integrated Waste Mnangement
LCA	life Cycle Analysis
LULU	Locally unacceptable Land Use
MCDA	Multicriteria Decision Analysis
NIMBY	Not in my backyard
NOTE	Not over there either

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