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Management Models of Municipal Solid Waste: A Review Focusing on Socio Economic Factors

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Abstract

Waste management is a complex process that requires a lot of information from various sources such as factors on waste generation and waste quantity forecasts. When operations related to promotion of waste management systems are considered it is observed that generation of waste and planning is found to be influenced by different factor of which are impacted by socio demographics. The main aim of this paper is to review previously tested models related to municipal solid waste generation and identify possible factors which will help in identifying the crucial design options within the framework of statistical modelling.

Keywords: solid waste management, empirical models, socio economic factors

1. Introduction

Waste management is a complex process that requires a lot of information from various sources such as factors on waste generation and waste quantity forecasts (Bovea et al., 2010; Zurbrügg et al., 2012). Data on the various factors that play a role in waste generation is important as it aids in estimating the consequences of changes in general conditions like economic system (Sjöström and Östblom 2010; Wang et al., 2011) demography (Bandara et al. 2007), domestic heating systems or waste management measures (e.g. increasing the rate of home composting) ((Lebersorger and Beigl 2011) and policy measures (Mazzanti and Zoboli, 2008). A number of studies have focused on the influence of socio economic factors in a bid to understand, define and forecast the unit rate of waste generation and composition of solid waste (Mazzanti, M., & Zoboli, R. 2009; Bandara et al., 2007; Emery et al., 2003). Some of the most common variables that are analyzed are number of individuals in a dwelling, age, sex, land usage, communications, ethnicity of the populations and productive activities (Emery et al., 2003).

When operations related to promotion of waste management systems are considered it is observed that generation of waste and planning is found to be influenced by different factor of which are impacted by socio demographics including

Amount of waste generated and personnel required: This is directly dependent on the population density and other factors (Henry et al., 2006).

Cost of operations: Greater the amount of waste generated, greater is the cost of operations (Christensen, 2011).

A significant issue that every nation faces is the need for a proper disposal system of the huge solid wastes that are generated every year. According to (Alhumoud, 2005; Christensen 2011), developed countries have always had to face significant difficulties in trying to devise a manageable way to dispose the waste that they generate. When it comes to non industrialized countries, (Koushki and Alhumoud, 2002; Al-Khatib et al., 2007; Henry et al., 2006), state that a lack of awareness and knowledge coupled with the increasing amount of lands being cleared for waste disposal and storage purposes are one of the major concerns.

Therefore although a specific waste disposal protocol or solution cannot be implemented or set due to the ever changing demographics and needs of the population, there is a need to identify the influence of socio demographic factors on municipal solid waste management systems which are currently planned and operated and arrive at different models which will help forecast better models of solid waste management.

The main aim of this paper is to review previously arrived at and tested models related to municipal solid waste generation and identify possible identifiers related to socio economic factors. From the review and discussion of models the research aims at arriving at limitations of previous models which will help in identifying the crucial design options within the framework of statistical modelling.

1.1 Defining Urban Solid Waste

Any and all solid waste that is created in an urban environment is classified as Urban Solid Waste (USW). USW is further divided into two different categories – RSW and NRSW. RSW refers to waste that is generated by households and NSRW is the waste that is produced by the commercial sector (industries, organizations). Both these sources create different kinds of waste that are classified as follows as identified by different authors (Buenrostro et al., 2001; Singh et al., 2011; Gomez et al., 2008):

(1) RSW: The solid waste that is generated by a single family or in a multiple family dwelling like an apartment.

(2) CSW: The solid waste generated by commercial institutions such as temporal ambulatory markets, supermarkets, markets, department stores and hotels.

(3) Industrial solid waste: the solid waste generated in all processes of extraction, transformation, and production.

(4) Institutional and services solid waste: the solid waste generated in recreational centres, like cinema theatres and stadiums, educational centres, libraries, private and governmental offices, museums, and archaeological zones.

(5) Special solid waste: This refers to the wastes that require special precautions and methods when it comes to their removal, management and disposal due to their hazardous nature or due to the requirements of the prevailing legal regulations. Usually such wastes are generated by automotive or industrial maintenance workshops, research laboratories, terrestrial transportation terminals, airports, medical institutions or facilities, drug stores and veterinary facilities.

When it comes to making appropriate decision in relation to the waste management of urban solid waste (USW), two factors are important – the total volume and composition. Both these factors change with time and socio economic conditions (Singh et al., 2011). Socio economic variables are among the most important factors when it comes to planning management programs of USW in developing countries mainly because the socio economic variables are not yet fully understood (Maldonado, 2006). According to (Agamuthu et al., 2007; Hockett et al., 1995), the effects of socioeconomic variables such as income, level of consumption, and cultural and educational environment on the generation of USW are specific and vary from place to place

1.2 Impact of Social Demographics on Solid Waste Generation

In the residential sector, socio-economic status and housing characteristics affect not only the amount of municipal waste that individuals generate, but also how they manage it (Emery et al., 2003). When the level of participation as well as the overall waste segregation individuals in a community make at the source was considered there has been determination of a positive correlation (Noehammer and Byer, 1997). Apart from this positive relationship has also been identified when the frequency of collection (Singh et al., 2011), Apart from this a link has been identification between consumer participation as well as economic incentives (Thanh et al., 2010Maldanado 2006; Noehammer and Byer, 1997) provided and the time of collection of garbage (Folz, 1991). The degree of waste management has also been identified to have a direct link with the level of social pressure which is presented in the community (Barr et al., 2003). The design and management of any waste management program should be promoted in a manner that the needs of the different community members in terms of the actual requirements of their household is met (Lansana, 1993). The degree of variation of these needs among different housing types and areas thus will be a predictor of how effective the waste management system is making identification of the variation of waste generation across the socio demography an important aspect.The generation of solid waste is found to be different as there is a difference in the level of consumption pattern in different locations (Singh et al., 2011; Sjöström and Östblom 2010). When different consumption patterns are considered they are found to vary with a wide range of factors including environment, demography and socio economic factors. These factors need to be examined in order to identify and develop a solid waste management system which can handle as well as minimize the overall rate of waste generation (Wang et al., 2011).

A number of studies have examined the impact of socio economic and demographic factors on the generation of waste (Buenrostro et al., 2001; Banar and Ozkan, 2008; Afon, 2007; Hockett et al., 1995; Dyson and Chang 2006; Daskapoulos et al., 1998; Beigl et al., 2004).

From all these studies the most common factors which impact the generation of waste include the level of income, the overall size of the household, the level of education, the attitude towards the environment (Afon, 2007). However these effects are found to be different across different locations and may vary across countries, cities and even zones in one particular city. It becomes very difficult to predict the level of association between each of these factors on a larger level as what is a predictor in one level need not necessarily be a predictor in another (Banar and Ozkan, 2008).

From the review of literature on types of solid waste generation and importance of understanding impact of socio economic factors on managing solid waste it is identified that there is growing demand for availability of reliable information on amount and composition of waste generation which is characterized areawise. Measurement of waste generation according to different models needs to take into account the different socio demographic factors which will enable further evaluation of disposable habits, the current trends and changes which may occur. In order to the same it is vital to arrive at an effective model. The following section describes the methodology followed in arriving at these models.

2. Research Methodology

The researcher systematically searched the Science Direct, Sage and Emerald databases through March 2012 using the following key words: solid waste generation, solid waste management, household waste, municipal solid waste. References from published prospective studies, relevant reviews, and previous Meta analyses were hand searched for additional studies not identified in the database search.Five characteristic classification criteria were focused by a systematic review of 10 waste generation models and these include: modeling method, type of modeled waste streams, location, regional scale and independent variables.

2.1 Eligible Studies

1) Were focused on solid waste management.

2) Included models that were used in solid waste management.

3) That incorporated independent variables like Removal and utilization of solid waste.

4) Were published in the English language.

Studies not meeting these criteria were excluded. In addition to the above criteria's, studies that carried out a review of SWM and included a Meta analyses in relation to solid waste management were also excluded.

2.2 Data Extraction

The researcher independently extracted data using standardized data extraction forms. Disagreements were resolved by consensus or, when necessary, by a third reviewer. Reviewers extracted information on study design, including the duration of follow-up, the setting.

2.3 Classification of Criteria Used in the Study

2.3.1 Type of Place

Constituency (C): One of the main reasons for the smallest regional unit being a district is due to the readily available data and competence of regional planning according to (Hockett et al., 1995). In the current study, the term 'Constituency' refers to an administrative unit that includes cities as well as municipalities. This particular research design allows a proper coverage of the federal states (ParWtt et al., 2001; Hockett et al., 1995; Salhofer and Graggaber, 1999). According to (Bach et al., 2004; Gay et al., 1993; Karavezyris et al., 2002), ensuring that modeling is not just restricted to a particular place will ensure that the samples cover a significant number of small to medium sized municipalities.

Households (H): In the case of household related studies, relationship between a wide range of individual habits or characteristics of the representatives of the household itself are analysed. Generally the sample size is setermined to be anywhere between 40 and 800 depending on whether the study is considering a survey on a single household dwelling or an entire community. Typical manner of attaining the required information is through personal interviews and surveys. Due to data protection issues census information is usually not available on an individual level. According to Lebersorger et al., 2003), household community generally refers to the smallest administrative unit.

2.3.2 Type of Waste Stream

2.3.2.1 Material Streams

Material streams refer to all the waste that is generated by the final consumer and material streams can only be determined through input output analysis. This method is not aimed at taking into account the collection procedure that is applied mainly because of its nature. The records pertaining to the amount of waste generated is not necessary and may be required only for the purpose of validation. Other studies have used dependant variables that are based on other input – output analysis (Daskalopoulos et al., 1998; Christiansen and Fischer, 1999; Skovgaard et al., 2005).

2.3.2.2 Collection Streams

The waste statistics are derived from the official statistics when modeling of the total Municipal Solid Wastes is required (e.g., Beigl et al., 2004; ParWtt et al., 2001; Hockett et al., 1995; Chen and Chang, 2000) or the sum of all recyclables (ParWtt et al., 2001) or single recyclable materials, like glass, plastics or metals or paper and cardboard (Bach et al., 2003 Lebersorger et al., 2003 1) or single collection streams, like residual waste (Mertins et al., 1999; Grossman et al., Dyson and Chang, 2005; Jenkins, 1993;). Some of the models also address other ways of disposal of wastes, like private wiring, illegal disposal and informal collection, other than the officially reported waste streams.

2.3.2.3 Independent Variables

According to Salhofer (2001), there are two different ways to classify models when it comes to analysis of waste generation and they are:

- Factor models that use factors describing the processes of waste generation (Consumption or Utilization).
- Input–output models based on the flow of material to or from waste generators (Removal).

There are a number of independent variables that have been used to explain the overall quantity of partial or entire MSW streams. Some of these variables are mentioned in studies by Salhofer (2001), Beigl et al. (2003), Hockett et al. (1995) and Jenkins (1993). As per the above depicted classifications, grouping is done based on the various stages of product life cycle which are: disposal-related variables, consumption related and production and trade related.

Forecasting of future solid waste is important and this is where solid waste management models are extensively used. There have been a number of studies that have dealt with various solid waste management models and their uses. These models are discussed below

Karavezyris et al., (2002) in their study looked into the application of system dynamics and fuzzy logic to forecasting of municipal solid waste. The study delved into the impact of demographical factors as well as costs of materials recovery and facilities, environmental behavior, treatment and disposal schemes on solid waste management. The study concluded that systems dynamics can be used to forecast and manage municipal solid wastes in a efficient manner. Fuzzy logic modeling was used in this study and it was evident from the study that it could be used for modeling exogenous elements like influences and thresholds. This model discussed constituency based features by identifying different collection streams. It focused on solid waste removal only. The limitation in this study was that the parameters examined were curtailed to amount of waste generated.

The importance of planning and proper design of a solid waste management was again reiterated in a study by Dyson & Chang (2005). The authors clearly identified a limitation when it comes to research or system planning in relation to solid waste management and the limitation was the lack of official historical records of solid waste quality and quantity. These limitations mainly occurred due to lack of sufficient financial resources and lack of proper management

3. Results and Discussion

Table 1. Summary of reviewed references

Reference	Type of Place	Waste Streams	Type of Independent variables	Modelling method	Parameters examined related to socio demographics
Karavezyris et al., (2002)	Constituency	Collection streams	Solid waste Removal	Systems dynamics	Amount of waste generated
Dyson & Chang (2005)	Constituency	Collection Streams	Utilization	Systems Dynamics	Waste generated in relation to income and population
Chen & Chang (2000)	Constituency	Collection Streams	Utilization and Removal	TSA	Amount of waste generated in relation to yearly time periods
Chang & Lin (1997)	Constituency	Collection Streams	Removal	TSA	Waste generation in relation to seasons and density
Zhang et al., (2011)	Multiple cities	Collection Streams	Removal	Reverse Logistics Waste management	Amount of waste generated
Dalemo et al., (1997)	Urban Areas	Material Streams	Removal	ORWARE	-
Bandara et al., (2007)	Constituency	Household Waste	Removal	Univariate Regression	Amount of waste and type of waste generated in relation to income
Skovgaard et al., (2005)	Country	Material Streams	Utilization	Time Series Analysis	Waste generation in relation to household sizr, expenditure and population
Navarro Esbri et al., (2002)	Constituency	Collection Stream	Utilization	Time Series Analysis	Amount and time of waste collected and seasonal waste generation

Dyson and Chang (2005), in their study again used system dynamics modelling to predict solid waste generation which would greatly aid in the management of the municipal solid waste. A case study based research was undertaken by the authors and five planning models were considered based on the various kinds of system dynamics models. This study also concentrated on presenting a model which was constituency based and identified different models of collection. The study identified consumption and utilization patterns by including data on income and population density. The modeling results are directly useful for associated system planning with regard to site selection and capacity planning of Material Recovery Facility in the near future.

Chen & Chang (2000) in their research also stated that solid waste management system requires accuracy in terms of knowing exact amount of solid waste being generated. However, the authors also contend that the manner in which the amount of solid waste generated is predicted is different in both developed and developing countries. This study focused on the city of Tainan in Taiwan. The study discovered that grey fuzzy dynamic modeling helps in reducing the inconsistency between the predicted values and the observed values. This is also a constituency based study focusing on different collection streams. There is presentation of both utilization and removal related factors. The one disadvantage in this type of modeling is that there is only seasonal data available for waste generation without taking into account any other parameters.Once again lack of proper and sufficient financial resources and unavailability of a good management task force is stated as the main reason for the above stated differences. The authors therefore contend that a special analytical technique must be developed and applied before the subsequent system planning for urban solid waste management is carried out. With this aim in mind, the authors presented a grey fuzzy dynamic modeling model to forecast the amount of waste generated in an urban environment. Zhang et al., (2011) proposed an inexact reverse logistics model for municipal solid waste management systems (IRWM). The study developed an inexact reverse logistics model in order to better facilitate the interactions between production and transport planning and inventory features in the system. Some of the limitations of the study include the non inclusion of parameters such as resource conditions and differences in the legislation, economic and social conditions. This study though being constituency based also identifies a number of specific areas across different cities which is a strength. This study classifies waste collected based on the type of material and focuses only on removal of waste. Despite these specifics the lack of any parameters related to socio economic factors is a limitation to be acknowledged in this study. This model can greatly benefit managers to develop a good solid waste management program. The study concluded that this model could be further advanced through incorporating methods of stochastic or fuzzy parameters into its framework.

Dalemo et al., (1997) conducted a study into handling of the waste from urban areas. The study made use of an ORWARE model to simulate various scenarios in urban waste management. The study provides a detailed view on the energy turn over, environmental effects and plant nutrient consumption in relation to solid waste management. This study focuses on specific urban areas but does not classify specific constituencies in these areas. The study is focused on different material streams identifying removal of waste. The limitation of this study is that none of the parameters related to any socio economic features are identified. The study concluded that the model affects the input data to the model, i.e., amount and composition of waste, and transport distances and therefore information has to be gathered separately for each area that is under review.

Bandara et al., (2007) also carried out a study to develop an effective waste management strategy for a specific place. The study focused on determining the relation of waste generation and composition to socio-economic factors. Some of the socio economic variables that the study used were the population density and average income of the individuals. In addition to these variables, level od education, climate, religious and cultural beliefs, living habits and social and public attitudes were involved. The study focused on a suburban municipal area in Sri Lanka. The study identified that there is a reduction in per capita generation of waste when there in increase in number of occupants of one house. The study focused on a single constituency and identified only one type of waste which is a limitation. The socio economic factors identified include only amount of waste generated related to income

Chang & Lin (1997) conducted a study into solid waste generation and delved into the impact that time series intervention modelling has on it. The study concluded that recycling impacts is important when it comes to forecasting the amount of solid waste generation. This study is constituency based focusing of variety of collection streams. This study is unique in that it does not focus on consumption factors and focuses solely on removal of waste. The only factor examined is generation of waste without identifying population density. Furthermore the authors also determined that time series model will be a very useful tool when it comes to prediction of solid waste generation.

Navarro Esbri et al., (2002) proposed some tools for time series analysis and forecasting MSW generation. This study made use of a prediction based technique which focused on non linear dynamics which presented different performance measures by making use of a seasonal Autoregressive and Moving Average (SARIMA) methodology. The model presented a forecast model which clearly identified a possible practical implementation for an effective MSW management. In this study a community based waste collection approach waste classified across different waste streams and identifying consumption patterns was observed. However only amount and time of waste generation are identified.

Skovgaard et al. (2005) proposed a model for overcoming the issue by means of providing a forecast for all required predictors and MSW forecasts for potential users. By means of implementing comparable and predictable variable like socio-economic variables, the model can be promoted to greater extent. The independent variables are hypothesized, collected and analyzed. It is vital and complex to ensure for the quality of such data. Due to the issues related to data availability and comparability, there are restrictions with respect to the implementation of data intensive approaches. The model on the same context is determined to have major objective of developing prediction tool. The reader is determined to be enabled for making inter-temporal forecasts or inter-regional predictions. Due to the inadequate data with respect to model parameters, the most of the models are unfeasible. In this study a country level analysis was carried out by focusing on different types of material used. This identified consumption types and size of household and income in relation to population were identified thereby overcoming the limitations of previously cited studies.

4. Conclusions

The process of waste management planning considers the evaluation of impacts on existing and future waste streams are vital and essential aspects. It is evident from the literature review considering for the previous implemented approaches that there is variation to greater extent among the adapted models in the concept. The variations are determined regardless of solving the issues in similar manner. There are five aspects that describe the models:

- Focused regional scale that ranges from perspective of household to county
- Type of modeled waste streams
- Hypothesized independent variables

- Socio economic factors
- Modeling method

In order to determine critical design options that have impacts on information gathered and cost efficiency of waste generation models, procedural and systematic guideline needs to be developed

From the discussions on the concept in previous studies and paper the following aspects can be proposed

- Beneficial choices considering for regional sampling that includes number and size of observed areas
- Waste stream definition and investigation
- Select appropriate independent variables
- Model validation procedures

The findings of the study are derived from the practical analysis and consideration of two case studies having varying settings:

- Survey-based analysis of household waste generation at multi-family dwellings and
- A census-data-based development of a forecasting tool for cities

The hypotheses derived by means of comparing the two case studies make the suggestion that implementation of single optimum procedure is not adequate for varying research objectives and circumstances as there exists various issues related to planning process. Balancing of information gain and implementation costs are essential in order to establish or determine the minimum requirements and standards for modeling procedures.

From the review a series of general check list like aspects with respect to current models can be identified. It is identified that there is a need for an overall forecast model which identifies both planning, location, type of waste generated and future growth in waste generated per capita. The discussion in this review also reviews certain shortcomings. The study has focused on a small number of models while there are a many more models which may have better insights to share. The study has also adopted a purely qualitative approach without involving statistical tools. Future research which presents statistical analyses may enable better insight into current models.

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