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Land use Generator Based Solid Waste Estimation for Sustainable Residential Built Environment in Small/Medium Scale Urban Areas

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Abstract

Background: The paper is based on a study aimed at arriving a more rational method to estimate quantity of solid waste generated type-wise, replacing the per capita based system practiced at present. **Methods:** It tries to understand how 'residential land use and associated activities' based specific key generator parameters of solid waste in a small/medium scale urban area influence quantity of waste generated. Criticality of residential landuse and related generators are identified through a Delphi/AHP based expert survey. Their relationship to waste generation is established using a field survey conducted in 2 select wards of three cities in South India. A statistically relevant sample size of 150 households/ward was surveyed. **Results:** The results show that when solid waste estimation based on land use parameters is attempted for residential land use not only factors like household size, income and food habits matter but also factors like housing typology, educational back ground, household size, existing systems in place for waste management etc have a decisive role to play in waste generation. Results of the Delphi/AHP process showing landuse criticality and weightage of the relevant parameters of residential landuse are first presented. Then, the paper discusses the field survey findings linking the stated parameters to the type and quantities of waste produced in the surveyed cities. In conclusion, the paper briefly outlines a system that can be developed to estimate solid waste generation at a suitable level (like ward) incorporating the parameters listed. **Application:** At the application level, such a system will have superior quantitative and qualitative precision of waste estimation and thus can help better in waste management, capacity building and mitigation measures as the case may be.

Keywords: Generators, Landuse, Solidwaste Estimation, Sustainable Urban Areas

1. Introduction

Municipal solid waste management has become a serious concern in most of the developing countries in recent times.[1,2] According to United Nations conference on environment & development in 1992 (Agenda 21) environmentally sound solid waste management must go beyond the safe disposal of waste and be focused on minimizing the waste and maximizing reuse and recycling of waste[3]. To achieve this aim it is mandatory to know the generators of the municipal solid waste preferably from a landuse perspective along with their logistics and rationale as it can give directions on the quantity and type of solid waste generated and capacity building. Broadly land uses of municipal solid waste generation potential are residential, industrial, commercial, institutional and agricultural land uses, and construction and demolition process. A recent study reported that amongst the the impacts of residential landuses the highest weighted one is on the solid waste generation aspect[4].The first step to scientifically working out the quantity and break up of solid waste generated from a landuse perspective is to rank the major land uses based on their solid waste generation potential.

The per capita based system of waste estimation is followed in most of the urban areas in India. However, this system may not be an appropriate method of waste estimation in the Indian context, with increased population densities and irregular urban growth. Such a system

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works better for urban areas which develop in a planned manner based on a prefixed density of population. This system of assessment does not connect waste generation to the core activities that make up the waste creation, the socioeconomic background of such activities or the built environment grade/quality of the setting in an explicit manner for an urban area. Whereas, in the actual case the stated aspects have a serious bearing on the quality and quantum of waste created. Land use and associated activities is a major umbrella entity to encompass all the stated aspects. A system that aims at identifying solid waste generators from such a perspective can be a considerably superior and accurate method for realistic assessment of solid waste. The paper presents the case of residential land use related generators as identified through a Delphi process and refined through an expert survey process and how they perform in the case of select study area city contexts.

2. Research Questions & Objectives

Role of an effective solid waste management system is realized as an issue of paramount importance world over and it is found that uncollected and improperly handled solid waste can cause serious health hazards. In India, Municipal Solid Waste (Management & handling) Rule, 2000 stipulates that all local bodies should undertake segregation of waste and its collection, storage, transportation and disposal. However, most local bodies could not comply in time as they lacked systematically evolved waste data under the stated heads. As planning and local self-government bodies formulate master plans and other vision documents with due reference to land uses such as residential commercial industrial etc. of various types and classes, the proposed paper is majorly aiming to look at the solid waste estimation, management and infrastructure and capacity building from this point of view. However, the methodology is structured so as to capture other extraneous factors of influence apart from the landuse as well.

Some of the research questions that the paper addresses are

- What are the key generators of solid waste in an urban area of designated land use, say residential?
- What is the role of these generators in regulating the quantity of waste generated as verified from an empirical context?

Based on the above research questions, the objective of this research paper is to understand how 'land use and associated activities' based specific key generators (and their characteristic parameters) of solid waste in a small/medium scale urban area is related to the quantity of waste generated.

3. Past Works

Compared to western contexts, municipal solid waste from India differs greatly in composition with respect to its organic and hazardous nature of constituents[5]. Relatively high percentage of organic matter in municipal solid waste of Indian cities has a direct link to the cities' socio-economic status. It is also true that the higher the socio economic status, the lesser the organic matter within the generated solid waste. But when we look at the total quantity of municipal solid waste generation, metropolitan cities with a higher socio-economic status generate more solid waste than small and medium towns[6]. Although it is an established fact that the quantity of municipal waste generation has a direct link to the socio economic status of a given area, root cause of municipal solid waste generation has considerable bearing on the type of human activity that the area supports. These human activities can be very well linked to the land use of that particular area[7].

After studying Municipal Solid waste management system of some of the Indian metro cities researchers suggested that a new survey need to be conducted to understand the solid waste generation potential of cities[7]. In India, Municipal Solid Waste (Management & handling) Rule, 2000 recommends source specific waste collection and transportation in addition to appropriate processing and disposal[8]. Data on quantity variation and generation of solid waste is a must to plan an efficient Municipal solid waste management system. As reported by Sakai et.al waste characterization is a must to plan an effective Municipal solid waste management system in fast growing urban areas[9]. In the study conducted[10] in Nagpur, it is reported that by knowing the type of land use classes within the urban area, details of waste characteristics can be assessed. Such a process can avoid dependence on open dumping/landfill which at present is the most sought after and only method for waste disposal (though having serious environmental consequences) in most cases.

A number of research works were under taken around the world to establish the relationship between various

variables affecting the solid waste generation of an urban area and thus try to help in planning a better solid waste management system. Population characteristics are considered to be one of the most important variables affecting waste generation[11].Another variable found to have some influence on solid waste generation is the average house hold income of the people residing in the given area [12].

A review conducted[13] about the available solid waste generation assessment models, reveals that there are mainly four types of data unit levels used for the assessment of solid waste generation, namely households, settlement areas, district level and country level. The study concludes that an investigation performed on household level may be of use only when applied to probe into a specific research issue or to obtain detailed basic information and is not applicable when you need larger scale information about the system due to several limitations. The review also reported that the waste generation assessment at higher levels for example district level & city level serves as primary planning information for better and accurate waste generation forecasting. In a research Lindh[14] established a positive relationship between the percentage of middle age group people in a population and its municipal solid waste generation potential. [13]Used factors like gross domestic product, population, population age structure, average household size, overnight stays, population density etc. for a statistical evaluation of municipal solid waste generation. This paper probes into the influence of similar parameters (evolved through the Delphi process) in creating waste for the study area that is the cities in South India.

Karadimas et al considered factors such as real estate commercial values, maximum building density factors, size of area in square meters and electricity bills of the commercial properties while modelling solid waste generation based on fuzzy logic[15]. Ghazi Jalili utilized Feed Forward Artificial Neural Network for the prediction of weekly waste generation in an urban area. A time series data on the already available weekly generation of solid waste for the last 5 years is used as the input in this model[16].

Even though it is a known fact that, human activities are the major cause of waste generation, not many studies are conducted to capture the relationship between the type of human activity and its waste generation potentials. Human activities can be very well explained with respect to the land use footprint of the area and this shapes the conceptual basis of the paper.

4. Methodology

The proposed methodology in its initial phase identified the critical land uses and their parameters based on the solid waste generation potential using a Delphi process. The Delphi technique, by definition, is a group process involving an interaction between the researcher and a group of identified experts on a specified topic, usually through a series of questionnaires. Objective of Delphi process in this research was to systematically identify the set of critical land uses and land use specific key generators of solid waste in a small/medium scale urban area. The intention of the Delphi technique is for the iterative process not only to solicit insight from experts, but also to reveal the areas where experts have consensus in their views. This consensus in expert's insight can be a valuable source of information to support decision making. The Delphi Methodology was carried out by identifying the problem, selecting a panel of experts to consult, administering various iterations of the questionnaire and evaluation process, and drawing conclusions based on the experts' consensus. The expert selection was the pivotal part in a Delphi process followed by an effective questionnaire preparation. The experts should make effective contribution on the topic from their qualification and the experience in similar fields. In this case, twenty experts took part in the process. The solid waste generators were initially identified through the Delphi survey process and later refined through an expert survey in which 94 experts of about 5 allied categories took part.

The relationship between the identified generators and solid waste generation was established based on the field survey conducted in select wards of three cities namely Thiruvanathapuram, Coimbatore and Kozhikode. For this landuse wise questions were prepared to elicit survey response that would reveal how these generators are connected to the quantity of waste created. The paper throws light only on the residential landuse context of the aspects mentioned. It was observed that apart from factors like household size, income and food habits, factors like housing typology, educational back ground, household size, existing systems in place for waste management etc. too have a decisive role to play in waste generation.

The ultimate aim of the research project is to arrive at a system which can estimate / predict solid waste generation at a suitable level (such as ward) based on the land use parameters and the field survey findings. This approach is a marked deviation from the existing per

capita based en-bloc system of waste estimation prevalent in most places at present.

5. Results And Discussion

Based on the Delphi process described in the methodology, the critical landuse (and their weightages) from the solid waste generation perspective was found out and is shown in Table 1.

From the table it can be noted that residential landuse has the highest relative weightage (0.349) and for this landuse their generators and their relative weightage were further identified through Delphi and expert survey processes as stated. These results are shown in Table 2. There are eleven generators in the table. Based on their prominence, correlation and ease of measurement of the eleven generators only five generators shown on Table 2 are analysed further for their influence on the quantity of waste generated. The results are discussed further. All results show per capita waste of the category concerned on the y axis for the generator relevance on the x axis.

Table 1. Relative weightages of Landuses from Solid waste generation perspective

Land Use	Rel. Weightage
Residential Land use	0.349
Commercial Land use	0.216
Industrial Land use	0.145
Recreation and open space Land use	0.122
Transportation Land use	0.065
Public Land use	0.058
Agriculture Land use	0.045

Table 2. Weightages of Key Generators/Parameters of Solid waste for Residential Landuse

Generators	Rel. Weightage
Population density of the area	0.202
Lifestyle/ Standard of Living of the residents	0.165
Household size	0.135
Income level of the residents	0.106
Food habits of the residents	0.084
Educational background of the resident	0.070
Waste collection system in place	0.061
Regulations in place for reducing solid waste generation	0.052
Awareness about solid waste menace	0.047
Average age of population	0.042
Housing typology in that area	0.036

One of the critical generators for the study is Income of the household in solid waste estimation. The study area group were classified into four groups and their varying relationship to solid waste generation is shown in the plot given as Figure 1.

For most cities, both Low Income Group (LIG) and Medium Income Group (MIG) create similar quantity of waste. In the city of Coimbatore, the quantity of non-biodegradable waste produced by the High Income Group (HIG) is disproportionately large. It is observed that across the cities, the highest quantity of per capita per day waste is created by the high income group (HIG) residents and 2 out of 3 cities show that as income level changes, quantity of waste generated also changes. Among the cities, the residents of the city of Calicut generate the maximum amount of waste across all income groups

The next plot, Figure 2 illustrates the influence of another important parameter on waste generation that is the waste disposal system adopted/in place.

For most cities, depending on the individual's option to manage waste, the quantity of waste gets regulated. For example, when there exists a public site available for solid waste dumping, residents tend to create more waste (as seen in the case of biodegradable waste). 2 out of 3 cities show a high amount of biodegradable waste being disposed by means of a public dumping site. As in-situ composting is being increasingly promoted, the residents who compost their waste tend to generate reasonable amount of waste as there is a way to manage it.

Housing Typology is another factor decisive in solid waste estimation. Residents in the study area were classified into four groups and the group wise relationship to solid waste generation is shown the plot given as Figure 3.

In the case of biodegradable waste, in all cities, high-rise residents generate the highest per capita waste whereas, in the case of non-biodegradable waste, the quantity reduces progressively from individual dwellings to high-rise apartments. Generally, apartment categories (both high-rise and low-rise apartments) generate comparable quantities of waste.

Figure 4 consolidates the relationship between the educational background of the resident and the solid waste generated.

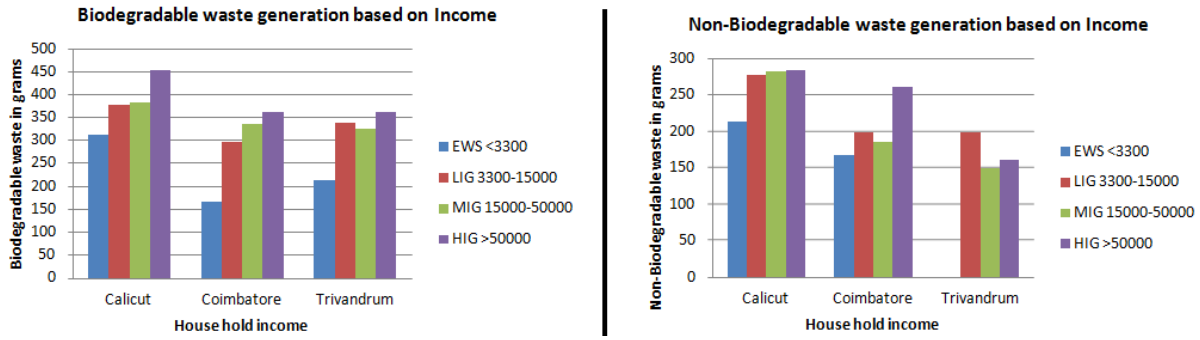

Figure 1. Comparison of income and types of waste generated.

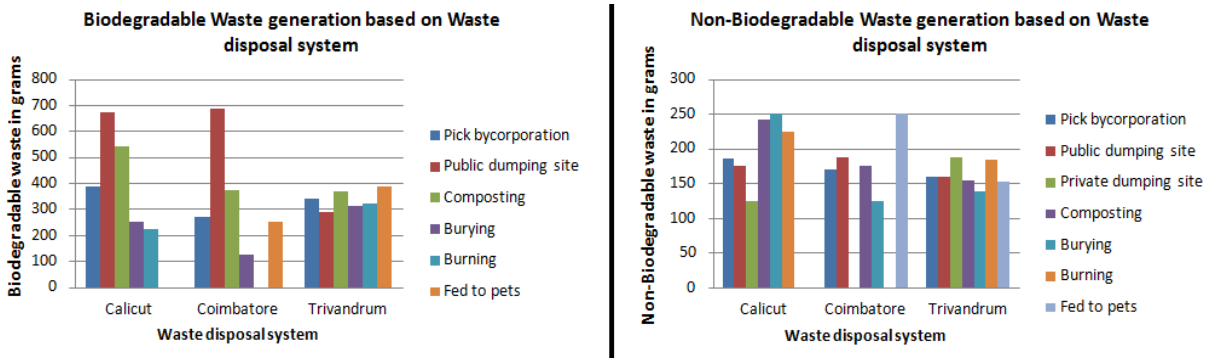

Figure 2. The waste disposal system adopted/in place.

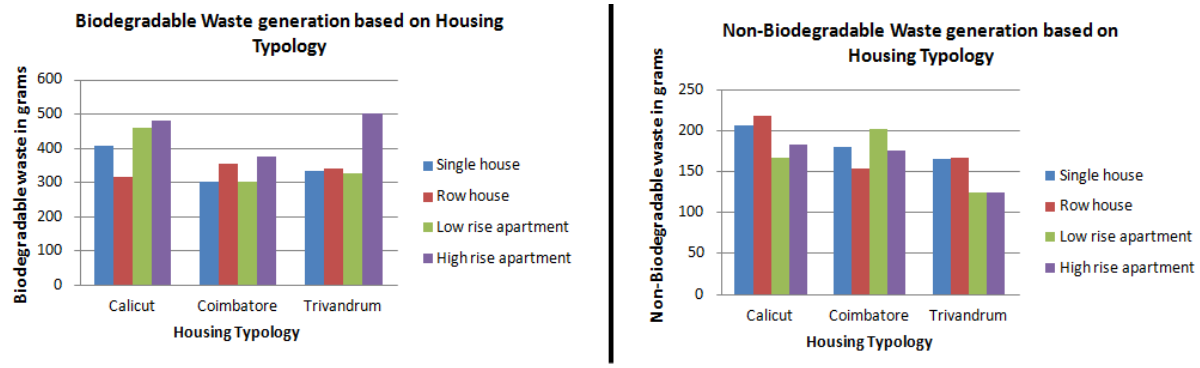

Figure 3. Comparison of waste disposal system and types of waste generated.

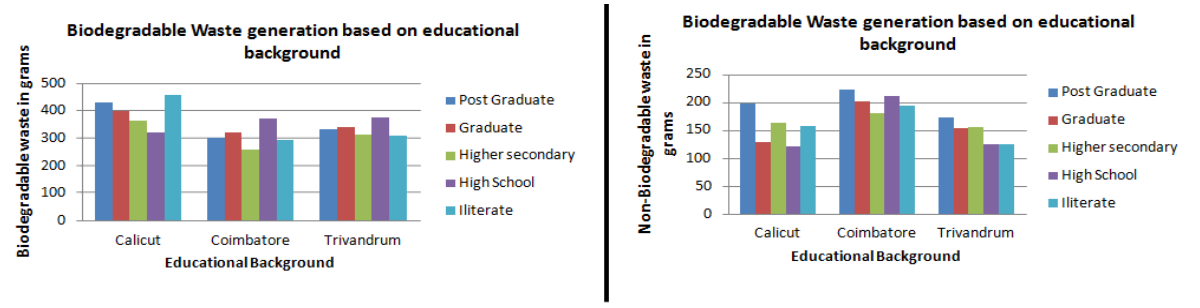

Figure 4. Comparison of educational background and types of waste generated.

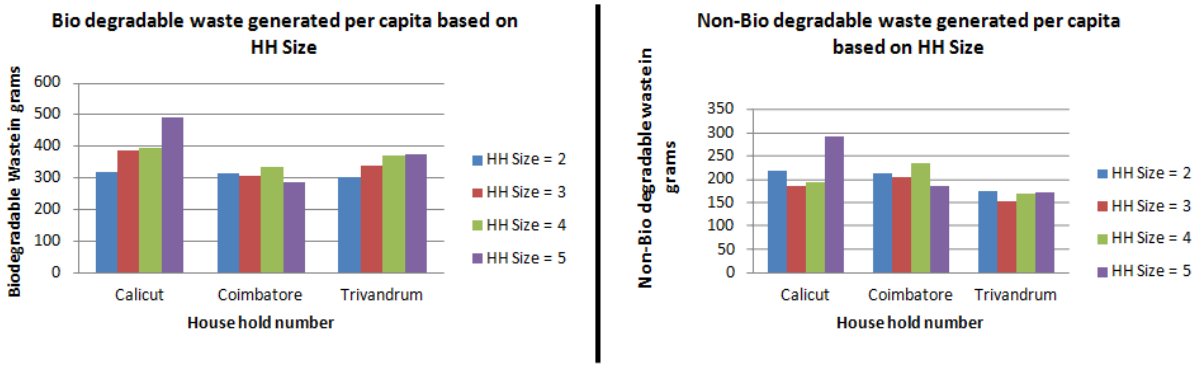

Figure 5. Comparison of household sizeand types of waste generated.

Contrary to perceptions, for most cities level of education did not play a major role in influencing the quantity of waste generated. Even when education categories were clubbed, no specific pattern could be seen. Ideally speaking, higher qualified citizens produce lesser quantity of non-biodegradable waste. However, the survey failed to prove this point. Here, higher qualified residents almost behave like higher income residents. It also hinted that reuse of waste may be minimal. The residents falling under the high school and higher secondary groups seemed to comprise a substantial part of the interest group and hence they did not make any sizeable contributions in the quantity of waste generated as per the field survey.

The household size for the surveyed cities is another significant solid waste generator. The relationships between household size and the quantity of per capita waste generated are shown separately in Figure 5.

As seen in Figure 5, for non-biodegradable waste, no specific relationship can be seen between the quantity of waste generated per capita and the household size. It is observed that among the three cities, the highest quantity of per capita per day waste is created by the residents of Calicut for all household sizes. 2 out of 3 cities show that as household number increases, quantity of waste generated/person also increases for biodegradable waste. Across the cities, there is least amount of variation in waste generation for the household size of 2 and maximum variation for household size of 5.

6. Conclusion

The paper consolidates the outcome of 1st phase of a research project to evolve a system of land use based solid waste assessment and management for a medium scale urban area. It identified critical land uses and ranked them from a solid waste generation perspective. For the residential landuse, generators were further identified through Delphi and Expert survey processes as they are accepted and reliable qualitative research methods followed in such research domains. Land use specific contributing factors identified as solid waste generators gives an idea on their weighted importance in creating solid waste and thereby provide valuable clues on framing development control guidelines which can significantly control and regulate solid waste generated in line with the management system in place to tackle the same.

The field survey at select locations was an attempt to reveal the way these generators influence the generation of solid waste of different categories. It captured the influence of some of the otherwise overlooked factors such as Waste disposal methods in place, housing typology and household size and there are interesting patterns emerging. It is proposed that these influences can be modelled landuse wise to estimate the category wise waste generated at the next level and such a system will be more reliable from a management perspective. The quantified profile of land uses as dealt in the paper emphasizes the need for making required provision to process and manage appropriate amount of solid waste as and when such land uses are planned. It will also help in correcting existing gap between provision of solid waste management systems and the demand for such systems for a given urban area from a land use angle. It can also help in treating this as an extremely sensitive aspect while planning certain land uses in specific zones in an urban area, and thereby avoid the possibility of new landfill to come up in a cityscape.

It can also support more precise and rational decision making in fixing budgetary provisions for infrastructure building and its distribution for solid waste management.

Limitation of the study is that these generators need to be further scaled and interpreted suitably to be translated to actionable indices of real life application in solid waste management. It is planned that the next phase of the research project will focus more on this. For a sustainable system of urban solid waste management it is important that we improve the quantitative and qualitative precision of waste estimation and in turn it will result in better waste management, capacity building and mitigation measures.

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