Waste Management 39 (2015) 26–34

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Identification of influencing municipal characteristics regarding household waste generation and their forecasting ability in Biscay

Iraia Oribe-Garcia *, Oihane Kamara-Esteban, Cristina Martin, Ana M. Macarulla-Arenaza, Ainhoa Alonso-Vicario

Deusto Institute of Technology, DeustoTech Energy, University of Deusto, Bilbao, Bizkaia, Spain

ARTICLE INFO

Article history:
Received 23 October 2014
Accepted 9 February 2015
Available online 11 March 2015

Keywords:
Household waste generation
Relevant municipal characteristics
Forecasting
Regression
Biscay

ABSTRACT

The planning of waste management strategies needs tools to support decisions at all stages of the process. Accurate quantification of the waste to be generated is essential for both the daily management (short-term) and proper design of facilities (long-term). Designing without rigorous knowledge may have serious economic and environmental consequences. The present works aims at identifying relevant socio-economic features of municipalities regarding Household Waste (HW) generation by means of factor models. Factor models face two main drawbacks, data collection and identifying relevant explanatory variables within a heterogeneous group. Grouping similar characteristics observations within a group may favour the deduction of more robust models. The methodology followed has been tested with Biscay Province because it stands out for having very different municipalities ranging from very rural to urban ones. Two main models are developed, one for the overall province and a second one after clustering the municipalities. The results prove that relating municipalities with specific characteristics, improves the results in a very heterogeneous situation. The methodology has identified urban morphology, tourism activity, level of education and economic situation as the most influencing characteristics in HW generation.

1. Introduction

Sustainable development of cities requires an integral waste management strategy that takes into account all the stages from the generation to the final disposal (Aranda Usón et al., 2013). When taking decisions about the design of infrastructures or the implementation of management policies, experts worldwide have recognized the importance of considering the whole system in a holistic manner (Coffey and Coad, 2010). Waste treatment is usually pointed out as the most important stage of Urban Waste (UW) management. Nevertheless, this stage is directly linked to waste quantity and quality (composition). An inaccurate estimation of the amount of waste generated difficulties to optimise the design of the required infrastructures and facilities. Under- or over-estimation of the UW generation has therefore significant consequences in terms of additional costs and environmental impacts (Beigl et al., 2003). In general, the accurate design of the waste management strategies requires of meticulous analysis of the generation data.

The success of waste management planning either for short-term (daily municipal management) or long-term (design of processing facilities), lies in the knowledge of the problem as well as in the accuracy and reliability of the used data (Chen and Chang, 2000; Navarro-Esbrí et al., 2002; Zaman and Lehmann, 2013). Forecasting models are useful to estimate future UW generation profiles. However, forecasting or estimation of waste generation is not an easy issue, mainly due to the generally little amount of available data and to the rapid change of factors that may influence it, such as socio-economic factors like gross domestic product in developing countries or the impact of the tourism among others (Beigl et al., 2008; Mateu-Sbert et al., 2013).

There is a huge range of forecasting methodologies applied to UW generation, which are classified in two wide groups: qualitative and quantitative models. The first ones are based on expert knowledge and do not necessarily use quantitative data. The second ones are more comprehensive and can provide better results when accurate data about the influencing factors are available (Armstrong, 2001). The literature shows a wide range of quantitative models, but three main groups can be distinguished: time series models, data-driven models and factor models.

Time series models aim at deducing variation patterns with time and show great ability to determine data repeatability. These models only need historical data about the dependent

* Corresponding author at: Deusto Institute of Technology, DeustoTech Energy, University of Deusto, Av. de las Universidades 24, 48007 Bilbao, Bizkaia, Spain. Tel.: +34 944139000.

E-mail address: iraia.oribe@deusto.es (I. Oribe-Garcia).

http://dx.doi.org/10.1016/j.wasman.2015.02.017
0956-053X/

variable. The simplest models used simple autocorrelation functions for the detection of autocorrelation embedded in time series data (Chang and Lin, 1997). Time series models have also been used successfully in order to assess the seasonal variations of waste generation (Denafas et al., 2014). Other models combine autoregressive techniques with seasonal exponential smoothing (Rimaityte et al., 2012), grey system theory (Xu et al., 2013) or support vector machines (Pai et al., 2010). Data-driven models run input–output data being able to identify their relationships. In the UW generation several applications have been presented using neuronal networks (Kumar et al., 2011) or support vector machines (Abbasi et al., 2013).

The main drawback of these methods is that they do not allow empirical reasoning about the influencing factors, which makes it difficult to identify the most important aspects in UW generation and consequently, to implement measures to reduce or control its generation (Noori et al., 2009; Shan, 2010).

Factor models or regression models are statistical models that provide insights of the reasons behind the UW generation. They allow identifying the interrelationships among different socio-economic factors with UW generation. These methods have been widely used in order to explain UW generation due to their mature theory and simple algorithms in order to forecast daily or annual generation (Lebersorger and Beigl, 2011; Ojeda-Benítez et al., 2008), at household, municipal or regional level (Afon and Okewole, 2007). Being easily applied, the main difficulty lies in the preparation of the data.

UW generation is a direct consequence of human daily activities, and it is closely related to consumption patterns, which are very local and generally depend on social, cultural, economic, environmental and demographic factors (Li et al., 2011). Therefore, applying techniques that encourage grouping observations with similar characteristics should result on more robust and precise models. Beigl et al. (2004) and Bandara et al. (2007) stratified municipalities according to prosperity and income levels deducing a multivariable regression model for each stratum. Other authors have applied GIS-based estimating techniques in order to include the spatial dependency of socio-economic characteristic in their models (Keser et al., 2012; Purcell and Magette, 2009).

The aim of this work is to develop models based on relevant socio-economic features regarding Household Waste (HW) generation at municipality level, and assess their forecasting ability. The resulting models will be able to support decision making process in the short-term planning of HW management. The applicability of the methodology followed is shown using real data of socio-economic features such as unemployment rate or tourist activity, from the province of Biscay.

2. Materials and methods

2.1. Case study: the province of Biscay

Biscay is one of the three historical territories of the Autonomous Community of the Basque Country, along with Gipuzkoa and Araba. Biscay is a territory with a long industrial trajectory, but ever since the deep deindustrialization, the economy has come to rely on the services sector. Located in the north of the Iberian Peninsula, Biscay has 1.1 million inhabitants, an average population density of 523 people per square kilometre, and an area of 2217 km^2. The province has 112 municipalities, the vast majority of which, 79 out of 112, are classified as rural (Fig. 1). According to the classification used in Biscay, rural municipalities are those with less than 5,000 inhabitants, and urban municipalities those with more than 50,000 inhabitants. The remaining ones are, those between 5,000 and 50,000 inhabitants denoted semi-urban municipalities (Basque Government, 2010, 2009).

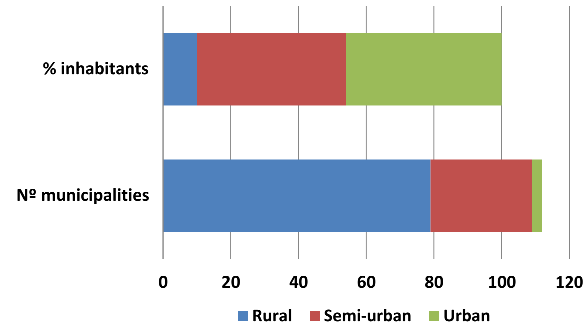

Fig. 1. Distribution of Biscay's municipalities by inhabitants according to waste management companies (Basque Government, 2010, 2009): rural (<5,000 inh), semi-urban (5,000 < inh < 50,000), urban (inh < 50,000).

Biscay towns are mainly grouped in communities (unions of services) in order to accomplish waste collection activities (Lozano Valencia and Lozano Valencia, 2008). All towns use separate collection systems for main recyclable materials. Glass, lightweight packages, paper and cardboard are collected mainly at drop-off points, and kerbside collection is used for mixed waste. Additionally, oil, textiles and batteries, as well as bulky and miscellaneous wastes, are collected separately by specific management services or at clean points. The 1999/31/CE European Directive (EU, 1999), transposed to Spanish legal framework by the Royal Decree 1481/2001 (MMA, 2001), established that in 2016 the amount of biodegradable waste sent to landfill must be reduced to 35% of the total generation in 1995, encouraging the separate collection of the organic fraction. Not only Biscay municipalities have started to implement totally or partially this collection system, 26 out of 112 municipalities, but also different treatments has been launched, such as composting or mechanical–biological treatment in order to accomplish that values (Biscay Provincial Council, 2013).

According to Biscay Council's terminology (Biscay Provincial Council, 2012a), Urban Wastes (UW) are classified according to Eq. (1). Industrial wastes are counted separately. Additionally, Household Wastes (HW) are divided into wastes strictly produced at home and similar waste produced at service establishments. Another difference is made with regard to the collection system. Wastes are distinguished between those collected separately, from those collected in a mixed way.

$$Urban\ Waste(UW) = Household\ waste(HW) + Commercial\ Waste(CW) \tag{1}$$

In 2012 UW were composed of 75% of HW, and 25% of CW. The 79% of HW (without taking into account building waste) were not collected separately, that is as mixed waste. The remaining 21% was collected separately (Biscay Provincial Council, 2012b). The waste streams separately collected were sent to recycle programs. The mixed waste was partially incinerated and partially sent to landfill, 52% and 27%, respectively. Fig. 2 shows the evolution of the fractioning ratio, that is, the ratio between the gross amount of one waste fraction collected separately with the total amount of waste generated. Thus, for the 2012, the mixed waste was nearly 80% of the total generation, paper and cardboard 5%, glass 4%, lightweight packaging 3% and other separate fractions 8%.

2.2. Methodology

The methodology followed to identify relevant municipal characteristics regarding HW generation is depicted in Fig. 3. Hereinafter the "dependent variable" will refer to the HW per