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Modelling the driving forces of the municipal solid waste generation in touristic islands. A case study of the Balearic Islands (2000–2030)

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ABSTRACT

The improvement of municipal solid waste (MSW) management in touristic islands has not been sufficiently studied, and by using the Spanish Balearics as a case study, a hybrid methodology has been developed which: (i) identifies the three most influential variables (driving forces) of the MSW generation system through an econometric model based on official historical data for a given period (2000–2014), (ii) develops a System Dynamics (SD) model of the evolution of MSW generation in this archipelago based on the same data and time period, and (iii) forecasts the performance of the MSW management system for a future period (2015–2030). Six different scenarios are considered with varying assumptions, objectives and management policies, while applying Scenario Analysis to the SD model developed.

The results show that by maintaining the current policies ("business as usual" BAU scenario) it will be impossible to meet the goals set by the Regional and the Spanish National Plans based on the European MSW Directive. However, by implementing the improvements proposed in the simulated alternative scenarios, the model predicts that by 2030, generation of MSW will have increased by 15% compared to 2014, mainly due to the effect of the Tourist Population which is 37.5% higher than the Resident Population. In addition, for the most optimistic scenario, the amount of MSW sent to landfills would decrease by 40%, and selective collection would increase by 30%, compared to 2014.

1. Background

The improvement of municipal solid waste (MSW) management systems is an issue of growing importance for the sustainability of any territory, and it is even more important in touristic islands such as the Balearics. An efficient and sustainable MSW management system is essential both for the health of the population and for environmental protection and conservation (Gonzalez-Martinez et al., 2012). Changes in per capita income levels, consumption patterns, demographic trends, and a population's sensitivity to environmental issues are directly related to MSW generation, and thus make it very challenging to find an adequate long-term solution (Adamides et al., 2009).

The Balearics are an relevant case study in terms of MSW management in touristic islands, due to their global importance, according to the Global Tourist Penetration Index, (McElroy, 2003). The contribution of the tourist industry to the Balearics total Gross Domestic Product (GDP) reaches 44.8%. Spain is one of the world's major tourist destinations, ranking third in terms of international tourist arrivals (UNWTO, 2014). Apart from being amongst the most relevant Spanish regions in terms of international visitors, this topic is also relevant because, like any other European territory, the Balearic Islands have to comply with the European Directive 2008/98/EC. All European countries must develop waste prevention plans and programs (articles 28 and 29) and thus, the Balearics have to comply with the Spanish National Waste Plan, and the Regional Master Plan (2008-2015).

The amount of MSW generated by islands can vary significantly, depending on the levels of affluence and consumption, industrial production, tourism, and other factors. Therefore, it is necessary to identify the main driving forces behind such variations. Changes and incentives in public policies may increase MSW generation. Furthermore, some of the relationships between those driving forces are dynamic and they have not been sufficiently investigated, so that feedback mechanisms may provoke non-intuitive responses.

To improve MSW management, multiple and interrelated decisions - within extremely uncertain and complex scenarios - have to be taken, for which the Scenario Analysis (SA) method can be of

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great help to decision makers by making their long-term planning more flexible (Salmeron et al., 2012).

In the study area, the improvement and planning of MSW management has, as yet, been minimally investigated; with only a few authors having studied compliance with the European goals regarding energy consumption and carbon dioxide emissions, as well as tourism and environmental pollution (Rosselló-Batle et al., 2010; Saenz-de-Miera et al., 2014; Bakhat et al. 2011). Other studies have focused on the impact of the tourism industry on MSW generation and costs (Arbulú et al., 2016; Mateu-Sbert et al., 2013; Arbulú et al., 2013). However, the previous studies have not developed econometric models to identify the main driving forces and develop forecasts using SD and SA for this archipelago. Although most islands face many difficulties in managing their MSW, these circumstances can also be seen in a positive light, because barriers to treatment and disposal practices may, at the same time, be incentives to the development of alternative strategies that are environmentally preferable. This research aims to bridge this gap.

Obviously, tourism plays an important role in MSW generation in touristic islands, however MSW management improvement in touristic islands has not been studied enough. Miller et al. (2015) analyse sustainable tourism (with special emphasis on ecotourism and eco-resorts) in terms of urban destinations. Tourist's MSW generation rate can reach up to twice the rate of the resident population (Shanshiry et al., 2011). Furthermore, the impact of tourism may be particularly problematic in insular environments (Deschênes and Chertow, 2004; Douglas, 2006; Diaz, 2007).

Lilai et al. (2012) suggest that the accurate prediction of MSW generation is crucial and essential for the planning, operation, and optimisation of any MSW management system. Gonzalez-Martínez et al. (2012) suggest that a sustainable MSW management system requires the incorporation of policies and governmental regulations, as well as a model of sustainable consumption, cost containment, and citizen education campaigns.

Many factors influence the MSW management system that should not be only based on adequate technological solutions, but also on environmental, cultural, legal, and economic factors. Vehlow et al. (2007), Su et al. (2007), and Triguero et al. (2016) analyse the relationship between MSW generation and the public policies implemented to improve MSW management.

Other authors study the existence of a positive correlation between MSW generation and GDP (Dangi et al., 2011; Johnstone and Labonne, 2004) as economic growth leads to increasing levels of consumption, which in turn cause increased MSW generation, and may thus lead to environmental degradation (Afroz et al., 2011; Márquez et al., 2008). However, environmental problems are not caused solely by consumption. In recent years, a general change of perspective on the investigation of environmental sustainability can be observed (Grunwald, 2014). A detailed understanding of whom the stakeholders are, and which responsibilities they have, is an important step in establishing an efficient and effective MSW management system (Abarca et al., 2013).

To estimate MSW generation, some models identify the factors that influence specific MSW flows (Beigl et al., 2008). Other studies conclude that the structure of the population (resident population and floating touristic population) is the main cause of MSW generation (Mazzanti and Zoboli, 2008; Dangi et al., 2011).

Concerning the application of the econometrics models to the improvement of MSW management, several studies must be mentioned: Ali-Abdoli et al. (2011), and Ojeda-Benitez et al. (2008). These studies develop models based on a multivariate econometric approach that considers the driving forces of MSW generation. Ghinea et al. (2016) forecast MSW generation by using a prognostic tool and a regression analysis. Weng et al. (2009) focus on MSW management and short-term projections of MSW generation. Mota et al. (2015) analyse the determinants of MSW management in Portugal. Sacratess and Govindaraj (2013) describe econometric methods based on the Logit and Tobit models, which serve to analyse the willingness to pay for the improvement of MSW management.

Regarding the use of System Dynamics as a modelling tool, Table 1 presents a wide sample of the studies carried out in different regions and periods.

Consequently, the main objective of this research is to analyse and evaluate the current MSW management system of the Balearic Islands, in the short- and long-term, up to 2030, building an econometric model to identify the driving forces affecting MSW generation in this archipelago, and forecasting its future evolution through System Dynamics (SD) and Scenario Analysis (SA), creating supposed scenarios that determine the behaviour of those driving forces, so that the current MSW collection system and treatment mix can be optimised.

The main contribution of this paper is the development of a prognostic tool to improve the consistency of decision making and the forecasts of future MSW generation in the Balearic Islands and other similar study areas.

Table 1
Summary of regional MSW studies based on SD and SA.

Author(s)	City/Region, Country	Period of study	Main factors analysed
Ardi and Leister (2016)	India	1994–2022	Waste Electrical and Electronic Equipment (WEEE) management systems
Al-Khatib et al. (2016)	Nablus, Palestine	12 years	Hospital waste generation
Ahmad (2012)	New Delhi, India	2006–2024	Mix of treatments
Beigl et al. (2008)	Steiermark, Austria	2008–2020	All the factors influencing waste generation (Household, Tourism…)
Cai and Lin. (2010)	Beijing, China	2000–2050	Population, waste disposal systems, waste administration systems and GDP influence
de Oliveira and Löbler (2012)	Southern Brazil	2000–2010	Waste generation and disposal
Dyson and Chang-Ni-Bin (2005)	Texas, USA	2000–2010	Population growth, household income, economic activity
Ghisolfi et al. (2017)	Brazil	1040 weeks, approximately 20 years	Waste Electrical and Electronic equipment (WEEE)
Giannis et al. (2016)	Singapore	2005–2030	Population, economy, waste recycling and waste disposal
Inghels & Dullaert (2010)	Flanders, Holland	1991–2006	Relationship between GDP, waste collection, reuse, recycling and disposal
Kollikkathara et al. (2010)	New Jersey, USA	2000–2010	Landfill capacity and related cost management issue
Marzouk and Azab (2013)	Egypt	2005–2025	Construction and demolition waste
Pai et al. (2014)	Karnataka, India	2000–2011	Impact of population growth, considering domestic waste and hospital waste
Purcell and Magette (2009)	Dublin, Ireland	1997–2006	Attitude and behaviour towards MSW
Wäger and Hilty (2002)	St. Gallen, Switzerland	1999–2009	Plastics management

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