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Modelling solid waste management solutions: The case of Campania, Italy

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ABSTRACT

The waste crisis in Campania has inspired a huge body of literature that has described its complex nature. Quantitative analysis in this regard provides useful insight into single aspects of the problem but from a static perspective. In this work, a dynamic model has been developed to analyse the interactions between the main elements of the waste system in Campania and their evolution over the critical time horizon. The model considers the process of capacity construction that has been developed to deal with the crisis and the flow of waste through the treatment options available, showing how the waste system behaves if such infrastructures are not able to cope with the amounts expected. The model also provides the analytical framework to explore the effects of alternative waste policies.

1. Introduction

The solid waste management process is complex as it involves multiple actors and dimensions that dynamically affect each other and cannot be described from an isolated and static perspective. Waste management systems require adequate analysis tools and systemic approaches have proven useful in supporting policy decisions by providing a comprehensive representation of those systems, considering the interactions between their main elements and their evolution over time.

The waste crisis in Campania is a clear example of this complexity. Since 1994, the region has experienced several periods of crisis that have revealed the weaknesses of its waste management system and, as some recent studies show, the problem is still the object of academic debate (Chifari et al., 2017; Ripa et al., 2017; Hornsby et al., 2017). The region was recently fined by the EU Court of Justice for failing to fulfil its obligation to create "an integrated network of installations to ensure waste disposal in the area" and there is still divergence at different institutional levels on the most adequate solution to the problem.

The public perception of the crisis, as the press and the policy-makers termed it, relates to a problem of capacity, the development of which has been impeded by local criminality and the community, the former making profits by disposing of waste illegally, the latter opposing the expansion of capacity because of its "not in my backyard" attitude. However, academic analysis provides alternative theories, where a more complex picture emerges that contradicts the "oversimplified" understanding of the problem and moves the focus away from the criminal elements and community to the political inability to deal with the complexity of the problem and define an effective exit strategy to the crisis (D'Alisa and Armiero, 2013; D'Alisa et al., 2010; Rabitti, 2008).

The waste crisis in Campania has inspired a huge body of literature (for a detailed review see D'Alisa et al., 2010, 2012) and different decision-making support tools have been proposed to deal with it: Chifari et al. (2017) analyse the municipal solid waste problem in Naples in 2012, based on a multi-scale integrated assessment combined with participatory process; Ripa et al. (2017) use life cycle analysis to identify critical points and driving factors on which to base waste management decisions; D'Alisa and Di Nola (2013) discuss the need to adapt waste management targets to the biophysical characteristics of the individual areas; D'Alisa et al. (2012) propose a novel set of indicators for the analysis of waste patterns; and Mastellone et al. (2009) assess different waste management scenarios by means of a material flow analysis.

These analyses provide useful insights into the diverse aspects of the problem, although they rely on a static perspective, without offering a comprehensive dynamic representation of it. The failure

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to implement the waste management plans approved to deal with the crisis (2008, 2012) demonstrates the need for dynamic decision-making support tools that take into account the interactions between the main variables involved and their evolution over time. This is also recognised in the latest regional waste plan, updated in 2016, where a scenario analysis is conducted to calculate the regional need for different infrastructures over the period 2016–2020. Therefore, in this work, a dynamic analysis is proposed by means of a system dynamics model developed to represent the waste crisis in Campania over the critical time horizon and explore the effects of different waste management policy scenarios over a 30-year time horizon.

System dynamics methodology has proven effective in handling specific waste management issues, including the management of electrical and electronic equipment waste (Ardi and Leisten, 2016; Ghisolfi et al., 2017), hospital waste (Chaerul et al., 2008), and solid waste in developing countries (Kum et al., 2005; Sufian and Bala, 2007; Sudhir et al., 1997). Karavezyris et al. (2002) propose an integrated framework for waste management in the city of Berlin, where the system dynamics approach is completed by the use of fuzzy logic to deal with qualitative variables. Dyson and Chang (2005) use system dynamics modelling to forecast solid waste generation in a fast-growing region based on a limited data sample. Inghels and Dullaert (2011) develop a system dynamics model to evaluate the effects of prevention initiatives in Flemish waste management.

Moreover, waste management models that focus on public policies have been developed to demonstrate how system dynamics is particularly suited to helping understand complex waste management systems, discovering their frequently counter-intuitive behaviour and exploring the effects of different policies and management options. For example, system dynamics models have been developed to analyse eco-design policies in Latvia (Dace et al., 2014), the long-term effects of local policies in Switzerland (Ulli-Beer et al., 2007), the impact of different policies on the overall cost of the transition from a landfill-dominated system to alternatives such as incineration and recycling (Mashayekhi, 1993), the dynamic effects of waste recycling market development (Chung, 1992) and the impacts of different policies to transform a wasteful society into a recycling society (Randers and Meadows, 1973).

The paper is organised as follows. Section 2 presents the background story of the waste crisis in Campania. Section 3 synthesises the system dynamics methodology. Section 4 illustrates the model and Section 5 describes the model validation. Section 6 illustrates the policy scenario results and, finally, Section 7 draws some general conclusions.

2. Background of waste management in Campania

Campania is located in south-west Italy. It is one of the most populated regions with almost 6 million people, and the one with the largest population density, with 430 inhabitants per km^2 in 2017. The capital is the city of Naples.

For more than two decades, Campania has suffered a waste crisis and the region has been an example of bad waste management. The crisis officially started in 1994, when the decreasing landfill capacity and failure to develop and implement a regional waste plan led the national government to declare a "state of emergency". A special commissioner was appointed with full power to rapidly prepare a waste management plan. By that time, landfilling had been the only treatment option and the limited legal landfill capacity had been reducing dramatically as a result of all the waste generated in the region, as well as the illegal waste coming from the rest of the country (D'Alisa et al., 2010; Greyl et al., 2010).

The plan approved in 1997 introduced the concept of integrated waste management. The main guidelines were: promoting separate collection; treating the mixed waste; recovering energy from the burnable fraction and stabilising the humid fractions; landfilling the residual waste.

To meet these goals, the separate collection (SC) target was set at 35% and seven mechanical biological treatment (MBT) plants and two incinerators (INC) were planned to be built by 2000. The MBT plants were designed to handle the waste remaining after separation and their main outputs were meant to be a stabilised organic fraction (SOF) to be used for land restoration and a refuse derived fuel (RDF) product. In the meantime, in accordance with the plan, the RDF would be treated outside the region until the incinerators began operating, in order to avoid its accumulation.

The construction of the planned infrastructures took longer than expected and, due to the lack of alternative waste treatment options, the regional landfill capacity was exhausted and waste started to accumulate in the streets. To address the crisis, temporary disposal sites were opened to cope with the waste generated (ARPAC, 2008). Waste was removed from the streets to external regions or foreign countries (ISPRA, 2008) or to unspecified treatment or disposal sites, as a result of which they did not appear in the official statistics, as pointed out by D'Alisa and Armiero (2013). From then on, emergency[1] solutions, such as opening temporary disposal sites or exporting waste to other regions in Italy or abroad, became a common management practice to free Campania's streets from waste.

As MBT plants started operating, RDF began to accumulate at disposal sites waiting for the incinerator, despite the planned solutions. However, the construction of one of the two incinerators planned, with a capacity of about 600,000 tons per year, took longer than expected and by 2008 it was still not in operation. In the meantime, about 6 million tons of RDF was stored throughout the region. This enormous stock pile was supposed to be burned in the incinerator, but its content was unsuitable for energy recovery use (Mastellone et al., 2009). In 2016, these amounts were still in storage, waiting to be incinerated, sent to landfill, exported or treated in an alternative manner. At the same time, the SOF produced was not used for land restoration as planned but disposed of into landfill.

The waste management system in Campania is currently organised as follows. Separate collection has increased up to 52% in 2016, due mainly to the improvement of door to door collection, half of which is organic fraction that is sent outside the region to produce compost due to the lack of adequate plants. Seven MBT plants treat the mixed waste, which is lower than their total capacity. The incinerator burns up to 700,000 tons per year and the remaining LF capacity is estimated at 560,000 tons. RDF is still stored throughout the region and measures have been proposed to deal with it, among them the use of underused MBT capacity.

Due to the lack of adequate landfill capacity, the region still exports waste to the rest of the country and, for this reason, in 2015 the European Court of Justice fined Italy and ordered it to pay a lump sum and a daily penalty as a result of Campania failing to implement an adequate waste management plan. More specifically, the Commission pointed out the lack of necessary waste infrastructures, among them landfills and incinerators, to fulfil the principle of regional self-sufficiency, which is a binding principle imposed to treat mixed waste within the region.[2] However, divergences have emerged with the regional government, which

[1] In this work, the term "emergency" is used to mean beyond ordinary practices. We have adopted this term as it has already been used by Mastellone et al. (2009) and D'Alisa et al. (2010).

[2] Self-sufficiency is not binding for separate collection, the treatment of which is subject to free market rules.