Chapter 26
An Integrated Model of Data Envelopment Analysis and Artificial Neural Networks for Improving Efficiency in the Municipal Solid Waste Management

Antonella Cavallin
Universidad Nacional del Sur, Argentina

Hernán Pedro Vigier
Universidad Nacional del Sur, Argentina

Mariano Frutos
Universidad Nacional del Sur, Argentina & CONICET, Argentina

Diego Gabriel Rossit
Universidad Nacional del Sur, Argentina

ABSTRACT

In the last decades, integral municipal solid waste management (IMSWM) has become one of the most challenging areas for local governmental authorities, which have struggled to lay down sustainable and financially stable policies for the sector. In this paper a model that evaluates the efficiency of IMSWMs through a combination of Data Envelopment Analysis (DEA) and an Artificial Neural Network (ANN) is presented. In a first stage, applying DEA, municipal administrations are classified according to the efficiency of their garbage processing systems. This is done in order to infer what modifications are necessary to make garbage handling more efficient. In a second stage, an ANN is used for predicting the necessary resources needed to make the waste processing system efficient. This methodology is applied on a toy model with 50 towns as well as on a real-world case of 21 cities. The results show the usefulness of the model for the evaluation of relative efficiency and for guiding the improvement of the system.

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INTRODUCTION

The ways in which waste is disposed reflects many relevant features of a society. The differences in garbage production may arise from the corresponding differences in the industrial structure, the physical distribution and the health considerations among districts (Gören, 2015). Municipal Solid Waste (MSW) disposal has become an increasingly serious problem in many parts of the world. In general, a greater economic prosperity and a higher percentage of urban population leads to a larger amount of production of waste (Aziz & Abu, 2016). The amount and type of waste generated is largely influenced by geographical and socio-economic factors. These factors include the population, the size of households, the age structure, the distribution of income, the type of dwelling, the geographical location and the time of the year, as well as the average standard of life. Furthermore, it depends on the frequency of collection and the characteristics of the source area (Chatsiwa, Mujere & Maiyana, 2016). In this work, the efficiency of systems of Integral Municipal Solid Waste Management (IMSWM) is analyzed and evaluated. In the context of resource shortages, either technical or budgetary, and in the face of an increasing rate of garbage generation, the correct management of the IMSWM is one of the main challenges for local governments that, no matter the size of the cities, aim to a path of sustainable development (Schejtman & Cellucci, 2014). Municipal Solid Waste Management (MSWM) is defined as the class of independent and complementary activities that constitute the process of dealing with waste in order to reduce the impact on the environment and the quality of life in a city. IMSWM encompasses in an integrated way activities as garbage generation, collection, transport, treatment and final disposition. The objective of the IMSWM is to enhance the appreciation of municipal waste, i.e., the transformation from waste into resources without endangering human health or the environment. These activities are carried out in suitable processes that cut down the amount of waste that ends in final disposition and, additionally, reduce its impact on the environment. Environmental management policies are aimed to prevent pollution, preserve natural resources, and reduce environmental risks while creating an environmentally friendly image for different stakeholders. Effective waste management methods reduce the consumption of natural resources and lower the ultimate needs for waste disposal (Kasemsap, 2017). MSWM has become an integral part of the urban environment to ensure safe and health human while considering the application of sustainable economic growth technology.

To run a successful IMSWM system, it is necessary to define and apply adequate indicators of performance. Although the activities of the system consume time, human resources and money, they should be considered more as an investment than expenditure. This becomes obvious upon the realization that the current increment in the Municipal Solid Waste (MSW) generation rate is not sustainable in the long run, not only because of budgetary limitations but also because of the limited amount of land that can be used for landfills, i.e., with the proper chemical conditions for dealing with garbage. Adequately designed indicators are useful for identifying the drawbacks of the systems and the adequate ways for improving them. Additionally, they are crucial for raising social and governmental awareness on how the incorrect handling of MSW affects human and environmental health (Inter-American Association of Sanitary and Environmental Engineering, 2005). In this way, social pressure can force governments to invest in improving the sustainability of MSWs and enhance the general welfare of urban areas. Indicators can also help to distinguish those cities that run efficient MSW systems. They also help to detect the connections between different environmental variables, facilitating the anticipation of risky situations for water supplies or wildlife. As it is usual in the design of indicators, IMSWM ones are generated combining straightforward parameters: frequency of garbage collection, size of the vehicle

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