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# Identification of waste packaging profiles using fuzzy logic

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ABSTRACT

An important factor in the environmental crisis faced by modern civilization is the waste produced by a great diversity of commercially available basic household products. An important step in measuring the impact of these organic and inorganic wastes in a community is to characterize the products consumed by families of different socioeconomic levels. In this work we present a method to identify consumption and waste packaging profiles based on household demographic data and type-specific consumption products. Our approach is based on fuzzy logic techniques to deal with quantitative and qualitative information for assisting in the decision making process when dealing with solid waste. This approach was implemented to process the information from a database containing domestic waste produced by families of different socioeconomic levels in a Mexican city. The data were taken from products consumed in 123 dwellings. Different types of packaging materials were classified as metals, cardboard, plastics, and glass. Household demographic variables were included such as level of schooling, number of inhabitants per dwelling, family income, and amount of waste generated. The results achieved show that when correctly combining the variables of a family, a more accurate approximation to the real packaging waste generation profiles may be obtained. The techniques applied in this research were successfully adapted to face problems that until now were difficult to treat, allowing to process information in which inexact values or subjective terms are handled.



## 1. Introduction

The 20th century society requires a great deal of satisfaction provided by means of industrialization and marketing processes. These processes represent the exploitation of natural resources and the generation of large amounts of waste with different compositions. Grodzińska-Jurczak et al. (2004) point in that this can be attributed to a boom in product packaging (mainly plastic).

Therefore, the consumption practice of our society in this century causes problems of contamination by the amount of waste that it generates without recovering the value which they have as residue. On this matter Tsiliyannis (2005) indicates that the packaging waste constitutes a significant component of the municipal residues based on its volume.

Thus, the generation of packaging waste is related to consumerism, closely related to the system of basic needs in which modern society exerts influence to drag the consumer into the disposable culture (Ojeda, 2005).

The wastes produced by human activity, lose their value when discarded. McDougall et al. (2004) indicate that the lack of value is related to the often unknown mixed composition of the waste. Therefore, waste segregation generally increases its value when there are possible uses for the recovered materials.

At present, consumption is one of the largest distractions of society because each family tries to satisfy its needs in the most practical and possible way (Ojeda, 2006). Likewise, waste generation continues to increase because the market economy offers a larger quantity of disposable products, which in addition are offered in a wide variety of designs and of packaging, generating packaging wastes and additional packing such as bags, cans, cardboard, glass, plastic, wood, paper, aluminum and tetra-pack among others, generally thrown away in the waste. Calver (2004) indicates that the transformation packaging is due to the changing lifestyle of consumers. Packaging is essential in modern society as it allows an enormous variety of products to reach the consumer intact, in proper hygienic conditions and general with pertinent information regarding the brand, the product and its usage.

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Packaging waste represents around 17% of urban solid waste by weight and 3% of the total waste flow. In recent years, this percentage has undergone an important increase as a result of the changes produced in the habits of consumers and the types of commercial distribution, which seem to favor more and more the packaging of products and in smaller quantities (individual portions, product units, small packs, etc.).

Packaging is a material meant to provide specific services, to contain, protect, transport and preserve a product. Therefore, its function will depend on the way the different needs for which they have been created will be satisfied. In this sense, Vidales (2003) indicates that since its first commercial appearance to the present time, packing has become an element very useful within the complex network that has been woven to satisfy many needs of human beings. For that reason it is important to analyze the generation of packaging wastes taking as a reference the characteristics of generators, which in this case is the family. To investigate the generation and composition of packaging that are commonly found in domestic waste, represents a challenge for the waste management research. As the composition of packaging materials, the function of the packaging and the volume generated, among others, helps to propose strategies for waste management practices. In this sense, it is important to find ways of analyzing the problem in order to offer alternative solutions. Therefore, in this paper, fuzzy logic is applied, being a tool which has been tested in expert systems (Jian-Da et al., 2007) and in other applications (Chang, 1997; Mohamed and Côté, 1999; Yukun and Yufeng, 2006; Ami et al., 2008; Pei-Chann and Chen-Hao, 2008; Shih-Ming and Shyi-Ming, 2008).

Fuzzy inference systems have also been applied in the field of solid waste. Chen and Ni-Bin (2000) developed a dynamic model by applying fuzzy theory to predict waste generation in an urban area taking a limited number of samples. Al-Jarrah and Abu-Qdais (2006) used an intelligent system based in the fuzzy inference system to approach the problem of selecting a site for a sanitary landfill. In another study, Nie et al. (2007) developed and applied a model for the planning of a solid waste management system under uncertainty, using Interval-Parameter Fuzzy-Robust programming (IFRP).

In this study, fuzzy logic is applied because it happens to work with mixed data type (quantitative and qualitative) of two different database structures. Fuzzy logic works with rules to generate knowledge from the databases, and the rules are recognized as an effective and natural means to transmit knowledge between humans, to make and to justify decisions (Moreno et al., 2006).

One of the problems which the experts in solid waste face, is to know the waste generation rates and the composition of the waste, for that reason it is important to work with tools that advance knowledge about the household generation behaviors extracting information from existing databases which have been developed.

One of the types of wastes that are generated is packaging; therefore fuzzy logic is applied to investigate the profiles of generation by family, considering that it involves qualitative and quantitative variables. This tool is adapted to produce generation profiles of the amount and weight of packaging as a function of family characteristics.

## 2. Methodology

In order to complete this study, the results of a research carried out by Ojeda (2007) were analyzed. This research was conducted in three neighborhoods of the city of Mexicali, which were selected for their socioeconomic stratum (high, medium and low). The research was done in these three neighborhoods, with the waste generated by the selected families during 8 consecutive days.

The sampling work for this research was done in three stages. In the first stage, a survey was used in order to learn about the family's basic characteristics, such as number of members, level of education, income, etc. The second stage consisted in the collection of samples during 8 consecutive days from the households that had accepted to participate; and, in the third stage, another instrument was applied, providing information related to the consumption habits characterizing each inhabitant by house, as well as the environmental knowledge that they have.

The information obtained from the three stages studied was stored in two especially designed databases to allow us make a descriptive analysis of the consumption habits, family structure and the generation of waste, among others. Nevertheless, the databases have not been data mining in their totality; it was necessary to apply tools to obtain information of the analyzed databases. To advance in the data analysis validation of the information required a normalization processes applied to the original database in order to eliminate, capture errors or redundancy in the information, preventing wrong interpretation of the information.

Once validation was achieved, basic statistical analyses (average, variances, correlation and factorial analysis) were performed to identify diverse panoramas of data behavior and to find existing dependent and independent variables, to obtain the proposed objective of finding profiles of generation of packaging by family. After identifying the dependent and independent variables (see Table 1), a new data base matrix was structured containing the information necessary to obtain the first profiles of the families.

In order to generate the input data ($x$) as the demographic data of the house, defined by the number of inhabitants by house, level of education, family type, number of bags analyzed and income by house, and the output data ($y$), defined to know the generation of packaging waste by house by weight and by the number of packaging materials. The output variables are: the amount and weight of packaging discard by house and by type of material (plastic, cardboard, metal and glass) (Table 2).

The data matrix presented in Table 2 groups the characteristics of the households, including data related to the generation of waste packaging per household in order to define rules that may reflect the quantity and weight of the waste packaging that the households with those attributes tend to discard. To do so, matrix data are inferred. This matrix consists of 123 tuples with 13 attributes

**Table 1**
Definition for the matrix variables

| Variables | Definition |
|---|---|
| Inhabitants | The total members of a single house. |
| Level of education | Last scholastic degree of the family parents. |
| Income | Income reported by house. With this variable the socioeconomic levels are inferred, the criterion to determine it is based on the minimum wage (MW).[a]<br>Low—income of 1–2 minimum wages.<br>Medium—income of 3–5 minimum wages.<br>High—superior to 5 minimum wages. |
| Family type | Nuclear—the typical family formed by father, mother and son.<br>One-parent—only a father or mother and children.<br>Extended—family who shares home with one or more relatives (grandparents, uncles or nephews). |
| Number of bags | The number of bags analyzed by house. |
| Quantity of waste packaging | Amount of articles by type of packing (plastic, cardboard, metal, glass). |

[a] The minimum wage is the salary unit in Mexico to pay a worker, and is equivalent to 50.57 Mexican pesos.