



## Identification of behavior patterns in household solid waste generation in Mexicali's city: Study case

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### ABSTRACT

A strategy of household waste data analysis is proposed in this work, based on the WEKA workbench, developed on the Pattern Recognition community. The analysis was conducted on data collected from homes at residential areas in the city of Mexicali, México. The data included information about solid waste produced and also the householder's commitment to the environment, assessed in a Likert's scale based on a questionnaire. A cluster analysis and a tree classifier constructed using the clustered data are presented. An analysis of the decision tree allowed to translate the resulting tree in a set of production rules. After the interpretation of these rules, we were able to predict an environmental behavior, based on the information about waste generation and the questionnaire answers. The rules showed a tendency to bring together members of the same family, concurring in all cases the reference to the same period of waste generation. The elements identified on each rule indicate that the socioeconomic stratum is an important factor, related to behavioral attributes and consumption habits, the main relationship is based on attributes of waste generation as glass, organics, paper, inert, mixer containers and sanitary. The discovered relationships between the cluster, socio-demographic, behavioral and waste attributes are presented and discussed.

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### 1. Introduction

Environmental pollution caused by daily solid waste generated at home has motivated a great amount of works about waste management and disposal. Most consumer products are designed, from manufacture, for an immediate consumption and consequently ending as waste in a short time. This fast waste generation process, coupled with the population increase, becomes a final disposition problem. Waste generation at home has motivated several studies in various areas of knowledge, seeking to minimize the environmental impact with a proper management program.

Consumption increase along with associated waste generation often stem from the belief of having the environment for human use and provision (Berglund and Matti, 2006), leading to a natural resources depletion. Despite the fact that humans understand the consequences of their actions, and can alter their behavior, they have accelerated the problem with a reckless behavior, using more resources than required.

Kastens and Turrin (2006), Davies et al. (2005), Devine and Lloyd (2003), Said et al. (2003) and Corral (2000) affirm that the human being is the principal factor in the accelerated pollution of the environment. Most of these studies propose to change people's behavior in order to modify the relationship between people and their surroundings to enable the preservation of the environment (Frey and Stutzer, 2006; Gärling et al., 2002; Saunders, 2003).

Suarez (2002) considers social consequences and personal conducts as representing one of the major important deals about the environmental problems. The knowledge of social and personal consequences of an anti-environment behavior is more important than the understanding of environment problems (Corral-Verdugo et al., 2003; Kaiser and Fuhrer, 2003). Therefore, there is a motivation to include not only technical aspects, but also behavioral ones, on the search for environmental problems' solutions (Stern, 2005; Tonglet et al., 2004; Fischhoff, 2001), in order to understand the relationship between people and their environment to enable the preservation of the environment.

Nowadays, products are extremely easy to acquire in different forms, in addition to the habit to spend unnecessarily and easily discard what no longer represents an utility, implying ecological deterioration. A large percentage of trash that we generate now results from the products we buy which become waste after use.

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Consumers can be influenced to have better environmental conditions, but to attain this, it is necessary to obtain all the information required, and also they must have the possibility to make pro-environmental decisions (Zaragoza, 2002). García-Mira and Real (2003) and Barreiro et al. (2002) affirm that more than the knowledge about the environmental problems, and the green effect, we must consider all the system believes. Most of the people do not change their home habits, since it requires making some sacrifices.

To determine environmental related behavioral patterns, it is necessary to gather together all the information that allows establishing the behavior patterns of both consumption and the environment (Tonglet et al., 2004). This information is obtained by the characterization and quantification of household solid waste (HSW) and also, by directly asking the residence' inhabitants about their environmental beliefs (Barr, 2007).

Socioeconomic variables and population composition should be considered to identify patterns of behavior in HSW generation studies. In this sense, Bandara et al. (2007) conducted an investigation to establish the relationship between socioeconomic factors and waste generation through a regression analysis. Bruvold in another study (2001) analyzed variables such as income and population density, however found no influence between income and the increase in the generation of municipal solid waste. Dennison et al. (1996) conducted a statistical analysis establishing the relationship between waste generation and socioeconomic factors; the results presented show no clear difference in waste generation between the richest and lowest income. In the absence of consensus about the results, it's important to continue along this line of research.

Some studies report results based only on the observed factors (field data) or on reported facts in polls or questionnaires, but not the relation among those variables. It is important to consider not only quantitative but also qualitative data, since there is an emergence of new procedures and techniques that allow extracting the hidden knowledge on a great amount of data. Tools developed on the Data Mining and Pattern Recognition communities permit to analyze new qualitative data in order to obtain logic rules (Grossman et al., 1999). In this paper, a study is presented applying several data mining techniques to waste and behavioral data collected on a residential area in the city of Mexicali, México.

### 1.1. The study city

Baja California a Mexican state has a population of 2,961,009; it is composed of five municipalities. Mexicali city is the capital of the state with 885,277 people; it has one of the highest per capita incomes among all Mexican states (Collins et al., 2005; Arellano and Fullerton, 2005). Mexicali is located in the north-west, 198 km from the Pacific coast, sharing a border with the state of California (USA) (Fig. 1). One of its important characteristics is a rapidly growing population with increased industrialization and urbanization, producing a considerable pressure on the region's underlying ecosystems. The combination of those factors is the principal source of the region's environmental problems (Programa Estatal, 2007).

Baja California's government development plan (Poder Ejecutivo de Baja California, 2006) considers the family as the basic and most important social structure in the community, observing that migration dynamics generate unfavorable social situations disrupting family's cohesion, reflected on actions against the environment.

According to the data from Mexico's National Institute of Statistics, Geography and Informatics (INEGI for its Spanish initials, 2005) the characteristics of private homes in Baja California are above the national average. The state is among the top five in terms of availability of automobile, computers, telephone, refrigerator, television. Most of the homes have a kitchen room, piped water,



Fig. 1. Mexicali, capital of the state of Baja California, Mexico, It is situated along the state's northern border with the U.S. State of California.

electricity, sewage, among other aspects giving an indication of people's welfare.

Baja California obvious progress setbacks on the environment. Currently an environmental information system to measure and assess progress is missing. This insufficient information (databases, environmental statistics and indicators) limits the ability to manage the agencies and institutions dedicated to the conservation and protection of environment in the state. These information instruments are becoming indispensable tools for government and society to have a clear, current state of our resources, in order to measure the effectiveness of the programs and actions implemented in recent years (Programa Estatal de Protección al Ambiente del Estado de Baja California, 2006).

Waste generation patterns differ among cities in Mexico and the differences have not been studied yet. Buenrostro and Bocco (2003) and Ojeda-Benítez and Beraud-Lozano (2003) report the existence of a gradual change in the type of composition of solid waste, indicating an increase in plastic and paper waste, due to the growing introduction of other materials whose high durability and safety increase their demand. The composition in the southern zone of the country has greater contents of gardening waste, whereas in the largest urban zones the same waste appears in a smaller proportion.

The border region's per capita waste production is among the highest in the country. The differences include diverse consumption habits and purchase power of the population, per capita waste generation, population composition, productive activities, number of persons per dwelling and the influence of United States' consumer patterns (Ojeda-Benítez and Beraud-Lozano, 2003; Buenrostro et al., 2001).

The main objective of this study is to find out the characteristic features in household waste generation of different family struc-

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