Solid waste production and management in urban centre: An innovative approach

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Abstract

Solid urban waste management is a problem of increasing difficulty in the context of planning and can generate a serious threat to urban environment. This work aims to implement a KDD (Knowledge Discovery in Databases) analysis performed with Data Mining Tools able to find some relationships between quantity and quality of produced waste and different characteristics of population, that can be useful to help public and private waste managers to individualize to the best the educational actions previously quoted and specifically focused on every category of population.

Keywords

Waste management, Knowledge discovery in databases

Introduction

Recycling is one of the main goals of the last (VII) European Action Programme for Environment which proposes strategies to promote prevention, reuse and recycling and give up inefficient and harmful methods such as landfills.

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In Italy, only few municipalities have reached the established targets of separately collected waste and the most worrying thing is that the Regions that have an higher per capita production don't have an higher performance in the separate collection: this is because public managers are not able to promote among citizens good behaviours able to increase recyclable waste collection. This research is aimed to find what are the social and demographic groups most refractory to separate waste collection and identify the principal factors influencing the total production and the part of recyclable waste in relation to socio- economic and demographic characteristics of the population.

Extraction of rules

Database construction

For the extraction of rules, data related to demographic and economic structure of population of over 8000 Italian Municipalities related to 2011 were used (source: ISTAT-Population Census), namely:

- Demographic characteristics (Dimension, age classes);
- Cultural characteristics (Educational qualification);
- Characteristics of dwellings and family (Kind of families, Characteristics of occupied dwellings);
- Characteristics of economic activities **(**Employed and not employed people);

We also used data related to total production of solid waste and separate collection at 2001, divided into categories (Source: ISPRA - Superior Institute for environmental research), namely:

- Separate collection (percentage);
- Production per capita ((kg/inhabitant per year);

Primary data have been analysed and discretized in order to allow a better legibility of the rules obtained from their implementation within the data mining tool.
Data discretization was performed using the following criterion: for each variable previously defined, a splitting of values was operated, in order to obtain five classes, that are defined as Very Low, Low, Medium, High, Very High: the definition of upper and lower limits was studied separately for each variable, according to the distribution of values assumed, in order to obtain almost homogeneous classes with respect to the number of elements contained in each one.

Classification software

For this work we used open source software Weka, from University of Waikato (New Zealand): namely we used classification algorithms (Part e OneR) and a tool for Predictive Association.
Within classification, input data (training set) consist in a certain number of records (in our case all Italian Municipalities), each of them consisting in a series of attributes (in this case population and economic activities characteristic described in the previous chapter) and a class label, that is the target attribute of classification: we considered for the various attempts both the quantity of solid urban waste and of separated collected waste.
The rules can be of different kinds in relation to their support on database and their precision: a frequent rule contains many cases within database while a very precise rule is always verified at the occurrence of particular conditions: in our case we decide to point out only the most frequent relations, trusting that a relation that occurs in many cases must be quite real and neglecting those

relationships which, although very precise, cover only a small number of cases.
The software has been implemented even on regional subsets and we discovered very different relations considering the whole national territory or smaller portions, perhaps caused by the different management system related to the various areas.

Analysis of the results

During the rules extraction, the information contained within database was subdivided into various data subsets and all the variables comprise in each group were related with waste system indicators both separately and grouped in order to catch the best relations between them: combining more than two characteristics more specific rules were obtained, but containing a lower number of cases, while analysing separately the various characteristics more general rules were obtained.
First of all we found that total production of solid waste and the percentage of separate collection are inversely proportional in a very critical way and in many cases (over 2000) a very high production (over 560 kg per capita/year) corresponds to low and medium percentage of separated collection.
About characteristics of dwellings and families no regularities were found between production of waste and number of mono-component families, while for separated collection an inverse proportionality is found: this means that this kind of family has a low sensitivity to the differentiation and is therefore to be properly educated.A very strong direct proportionality has been found between total production and number of two components families: if they are in a low or very low percentage, waste production is low or very low too, while completely indifferent is the

percentage of three or four components families (couples with children?).Finally, the percentages of families with more than five components are inversely proportional to the amount of waste, that is to say that the more the family is large, the lower per capita production is.

For age classes, population between 30 and 60 years, the most economically active, greatly influences in a proportional way the production of waste especially in the case of low rates, but exactly the same relation was found for separate waste collection: population within this age classes produces a larger amount of waste but it also strongly influences with direct proportionality the amount of recyclable waste.

The size of the municipality greatly affects the amount of waste, because small and very small municipalities have a very low production, while for the wider municipalities production is very high, probably because they have a greater number of economic activities and a greater number of active population. However, there is no relation linking the size of the Municipality to a greater or lesser percentage of recycling waste and this highlights a very critical situation because increased productions doesn't correspond to an higher separate collection rate.

For the educational qualification, the percentage of graduates is strongly proportional to the production of waste, perhaps because the presence of more specialized people stimulates more consumerist activities and lifestyles. For what concern separate collection do not exist meaningful relationships towards the percentage of graduates and this reveals a critical situation because to higher production doesn't match a greater sensitivity toward separate collection: on the contrary, at a Regional level of Tuscany Region a strong direct proportionality between the percentage of graduates and percentage of waste collection was found.

For economic activities, in Municipalities with agricultural specialization the percentage of recycling waste is always very low or low in inverse proportion to the degree of agricultural specialization: this probably depends on the spatial dispersion of the settlements that makes difficult to separately collect. However, there is a very strong proportionality between the employed in trade and services sectors and quantity of production.
For what concern the movements there is a strong direct proportionality between commuting to work and total production of waste.
With regard to the non-active population, the presence of housewives is inversely proportional to the amount of produced waste, in the sense that where the housewives are very few, the production of waste is very high, while it assumes very low values where there are many housewives: a direct proportionality also exists between the percentage of housewives and separate collection.

The interactive website

Beginning from these first results we can identify some awareness and information campaigns towards population, that address specific "dedicated" topics in relation to specific characteristics: specifically, it is possible to identify different kinds of users and behaviours in relation to the rules arising from the K.D.D. analysis. The website, that has being realized in prototypal form, aims to create a structured "link" between administration and users.
Most of the interfaces on the web already now guarantee the population's access to most of the information related to waste management but few interfaces ensure the training of citizens and the exchange of information in the direction population-public administration.

From the home page the user can access not only to the traditional information (definitions, data, documents, research, laws) but also to the dedicated services: he can select one of the entries to which he considers to belong (citizen, entrepreneur, student, etc.) and then a survey will be given to him and used to identify a specific profile which match a campaign, which could be preparatory to participation in targeted events (e.g. Profile citizen/retiree, campaign on recycling, organization of meetings on the same subject that are also cause for aggregation, or profile citizen/family with children, campaign on systems for the reduction of waste generation, organization of meetings/workshops also combined with recreational and educational events like exhibitions of products built with recycling).This interface could allow the participants in educational campaigns to accumulate points through which they can access to facilitations (e.g., discount on waste tax, possibility of buying products in agreement with private companies opportunity to access public services, etc.). In addition, in order to exchange information, citizens can denounce or report facts by locating them on a georeferenced map in real time: the users can provide information to the institution on the efficiency of the service of waste collection (e.g. dumpsters crumbling, inadequate frequency of collection, bins not distinguished by type of waste , etc.) and same map can be enhanced with information provided by the institution itself.
A virtuous circle could arise between institution and citizen, in which the participation of citizens, and therefore their greater attention to "do well".

Conclusions

Actually, more detailed census and local data coming from different sources are in analysis for better understand what kind of "rules" can be considered as "general" and, on the contrary, if some others are only related to specific territorial areas in relation to different systems of waste management. Another future development is aimed to implement some validated rules at local level (census sections) for predictive tasks, in order to produce thematic maps in which the value of the production of waste and separate collection for each census section might be put into relation with the characteristics of the population or with other spatial characteristics of the studied area (e.g. density, shape of the blocks, etc.).

References

European Parliament (2008), *Waste Framework Directive 2008/98/EC*, Bruxelles

Han J., Kamber M. (2000), *Data Mining: Concepts and Techniques*, S. Francisco, Morgan Kaufmann.

ISPRA (2014), *Rapporto Rifiuti Urbani, [Urban Waste Report]* [http://www.isprambiente.gov.it/files/pubblicazioni/rapporti/RapportoRifiutiUrbani2014_web.pdf]

Lombardo S., Pecori S., Rotonda M., Santini L. (2005), Implementation of artificial intelligence tools to support the solid waste management service. A case study in Tuscany, *14th European Colloquium on Theoretical and Quantitative Geography - ECTQG'05*, Tomar, Portugal, September 9-13.

Quinlan J.R. (1986), Induction of decision trees, *Machine Learning*, 81, pp. 1-10