View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Clute Institute: Journals

Pollution And Environmental Indicators Using A Multicriteria Analysis

María-Carmen García-Centeno, Ph.D., CEU San Pablo University, Spain
Gema Fernández-Avilés, Ph.D., University of Castilla-La Mancha, Spain

ABSTRACT

Pollution and environmental factors are a core topic because they influence in air quality of the different areas of a city. This is why in this article we propose to apply a multicriteria decision aid method (the Promethee) to establish a ranking among twenty one districts of Madrid city. To develop this ranking we use objective and subjective criteria that contain information about pollution and environmental indicators in these districts. The results show that some districts are the worse and the best regardless the used criteria.

Keywords: Pollution; Environment; Particular Mater; Multicriteria Decision; Promethee

1. INTRODUCTION

Problems like global warming, acid rain and ozone depletion are well known but can seem remote from the daily life in all cities. Most of our economic activities are concentrated in urban areas where almost 80% of the European population lives. In urban areas transport routes and residential areas are often very close to each other and therefore transport is a major contributor to urban air pollution. Though residential and industrial areas are often separated air pollution travels over long distances and industries contribute either directly, or through background concentrations to poor air quality as well.

Environmental problems have been studied increasingly in recent decades because they can cause many health problems, such as, respiratory and cardiovascular, Mackay et al. (2010). In most cities air quality, pollution and environmental factors have improved over the past decades. The visible and noticeable air pollution (smoke, dust, smog) has disappeared from many cities due to local, national and European initiatives. Occasionally air quality poses an immediate threat: during industrial incidents or pollution episodes. Fortunately this is rare. In many European cities, air quality is a concern and it is therefore monitored around the clock. In most cities, industrial air pollution is, or tends to be replaced by traffic related air pollution. Air quality is therefore a common problem to almost all major cities.

In the city of Madrid, as in all large cities in the world, there is a monitoring network that measures the level of main pollutants, particularly harmful to human health, on an hourly basis. The information about these pollutants and other variables will be used as variables to rank different districts of the city of Madrid.

After this introduction the remainder of the article is structured as follows. Section 2 is devoted to show the Promethee metodology as a multicriteria aid decision method. Section 3 includes the main obtained results using objective and subjective criteria. And, section 4 concludes.

2. METODOLOGY

The Promethee methods were developed at the beginning of the 1980's and have been extensively studied, improved and used around the world in a wide variety of decision scenarios in fields such as business, governmental institutions, transportation and education, Brans (1982), Brans et al. (1984), Brans and Vincke (1985), Goumans and Lygerou (2000), Behzadian et al. (2010). These methods try to establish a preference order among the alternatives from a given set of alternatives, usually when there are multiple criteria of evaluation. To obtain this preference

order, first the decision maker needs a pay off matrix which has the information about the alternatives, criteria, weights and evaluation of each alternative for each criterion. From this pay off matrix a pair wise comparation will be made between all the actions for each criterion in terms of a preference degree.
The preference degree is an increasing function of the deviation: smaller deviations will contribute to weaker degrees of preferences and larger ones to stronger degrees of preferences. To facilitate the association of a preference function to each criterion, the literature has proposed the following six specific shapes (see Table 1):

Table 1: Generalized Criteria

Usual (No threshold)	U-Shape (q threshold)	V-Shape (p-threshold)
$H(d)=\begin{cases}0 & d=0\\ 1 & \lvert d\rvert>0\end{cases}$	$H(d)=\begin{cases}0 & \lvert d\rvert\le q\\ 1 & \lvert d\rvert>q\end{cases}$	$H(d)=\begin{cases}\dfrac{\lvert d\rvert}{p} & \lvert d\rvert\le p\\ 1 & \lvert d\rvert>p\end{cases}$
Level (q and p threshold)	**Linear (q and p threshold)**	**Gaussian (σ threshold)**
$H(d)=\begin{cases}0 & \lvert d\rvert\le q\\ \dfrac{1}{2} & q<\lvert d\rvert\le p\\ 1 & \lvert d\rvert>p\end{cases}$	$H(d)=\begin{cases}0 & \lvert d\rvert\le q\\ \dfrac{\lvert d\rvert-q}{p-q} & q<\lvert d\rvert\le p\\ 1 & \lvert d\rvert>p\end{cases}$	$H(d)=1-e^{-\frac{d^2}{2\sigma^2}}$

Where, q and p are respectively the indifference and preference thresholds. The meaning of these parameters is the following: when the difference of results is less than q, that is considered as negligible by the decision-maker and the preference degree is equal to zero. If the difference is greater than p, that is considered to be significant (p cannot be smaller than q). Therefore, the maximum value of the preference degree is equal to one. In some cases, when the difference is between the two thresholds, the preference degree is calculated using a linear interpolation. The Gaussian threshold σ is a middle value that is only used with the Gaussian preference function. To solve the problem, it is necessary that each criterion has associated a preference function with a weight (w_i), that indicates the preference of the decision-maker for the different criteria. Then, can be done for every one of the criteria comparisons between all pairs of actions to get the preference indexes matrix. The preference indexes are calculated as following:

$$\pi\left(a_i,a_j\right)=\sum_i w_i H_i(d)$$

where, $\left(a_i,a_j\right)$ are two different actions or alternatives; $\left(w_i\right)$ is the normalized weight of each criterion; and, $\left(H_i(d)\right)$ is the corresponding result for each preference function.

In order to position every alternative with respect to all the other, it is necessary to calculate the positive $\left(\phi^+\right)$ and negative $\left(\phi^-\right)$ flows. For each alternative, these flows are calculated as follow:

$$\phi^+\left(a_i\right)=\frac{1}{n-1}\sum_{x\in A}\pi\left(a_i,x\right)$$

$$\phi^-\left(a_i\right)=\frac{1}{n-1}\sum_{x\in A}\pi\left(x,a_i\right)$$

The positive flow quantifies how an alternative is globally preferred over the other. The better alternative is the one that has the larger positive flow. The negative flows are the opposite to the positive ones, that is, the preference degree with which the other alternatives are preferred to that alternative, therefore the better alternative is the one that has the smaller negative flow. Both the positive and negative flows can be used to rank the actions from the best to the worst to establish a preference order among the different actions.

The Promethee I partial ranking is defined as the simultaneous comparisons of the positive flows $\left(\phi^{+}\right)$ and negative flows $\left(\phi^{-}\right)$ rankings. That is, it is defined as the intersection of these two rankings. As a consequence, an alternative $\left(a_i\right)$ will be as good as another alternative $\left(a_j\right)$ if $\phi^{+}\left(a_i\right) \geq \phi^{+}\left(a_j\right)$ and $\phi^{-}\left(a_i\right) \leq \phi^{-}\left(a_j\right)$.

When there is a conflict between the positive and negative flows, the actions are considered incomparable in the Promethee I ranking and it is necessary to use Promethee II to solve the conflict using the net flow (ϕ). These net flows are calculated as following:

$$\phi\left(a_i\right) = \phi^{+}\left(a_i\right) - \phi^{-}\left(a_i\right)$$

The Promethee I is a partial preorder because includes preferences, indifferences and incomparabilities. However, the Promethee II is a complete preorder because includes preferences and indifferences.

2.1 Alternatives

The alternatives are several elements that we seek to establish a ranking. The alternatives used in this paper are the following twenty one districts of Madrid city: Centro, Arganzuela, Retiro, Salamanca, Chamartín, Tetuán, Chamberí, Fuencarral-El Pardo, Moncloa-Arava, Latina, Carabanchel, Usera, Puente de Vallecas, Moratalaz, Ciudad Lineal, Hortaleza, Villaverde, Villa de Vallecas, Vicálvaro, San Blas and Barajas.

2.2 Criteria

The criteria are the variables used to evaluate each district of Madrid city. They can be maximized (a district is preferred when the value of a criteria is higher than other) or minimized. Each criterion has a weight (normalized or not). This weight shows the importance of each criterion to establish a ranking between the different actions, but in this job we suppose that all variables have the same weight. In our case, to obtain the ranking among the different districts we use two types of criteria[1]: objective and subjective. The information about these objective and subjective criteria is shown in Table 2 and in Table 3.

[1] The information about these criteria is obtained from: http://www.airqualitynow.eu/pollution_home.php

Table 2: Description Of Objective Criteria

Criteria	Description	Max/Min
Green area	Number of land hectares, which are intended for park or woodland, situated within Madrid.	Maximized
Plant stand	Number of furniture or fixture to put ornamental plants directly in the ground or in pots.	Maximized
Trees	Number of trees there are in each district.	maximized
Carbon monoxide (CO):	This is an odourless, tasteless and toxic gas produced by the incomplete burning of materials which contain carbon, including most transport fuels.	Minimized
Nitrogen dioxide (NO_2).	This is an inorganic gas formed by combination of oxygen with nitrogen from the air.	Minimized
Nitrogen oxides (NO_x).	It refers to NO and NO_2. They are produced during combustion, especially at high temperature.	Minimized
Ozone (O_3).	It is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2) hydrocarbons and sunlight.	Minimized
Particular Matter (PM_{10}).	It is the term used for a mixture of solid particles and liquid droplets suspended in the air.	Minimized
Sulphur dioxide (SO_2).	The SO_2 is produced when the fossil fuels that contain traces of sulphur compounds are burnt.	Minimized
External noises	This indicator measures the gap between measured noise and the level of noise considered appropriate according to the activities that take place in a specific area. This gap is weighted with the percentage of affected population.	Minimized

Table 3: Description Of Subjective Criteria

Criteria	Description	Max/Min
External noises	This criterion shows the level of household satisfaction related to the problems in housing caused by external noises.	Minimized
Odor pollution	This criterion shows the level of household satisfaction related to the problems in housing caused by odors or pollution.	Minimized
Unclean street	This criterion shows the level of household satisfaction related to the problems in housing caused by the little street cleaning.	Minimized
Poor communication	This criterion shows the level of household satisfaction related to the problems in housing caused by poor communications.	Minimized
Shortage parkland	This criterion shows the level of household satisfaction related to the problems in housing caused because there are not many parks or gardens.	Minimized
Vandalism	This criterion shows the level of household satisfaction related to the problems in housing caused by crime or vandalism.	Minimized

3. RESULTS

To obtain which are the best and the worst districts in Madrid city we establish two different scenarios: the first is using the objective criteria and the second one using the subjective criteria. In both cases we suppose that all criteria have equal weights and the function under each criterion has been evaluated is the usual.

The positive, negative flows show there are not incomparabilities when we used the positive and negative flows (once again, the ranking in both cases is the same). That is the reason why we only show a graphical representation of the preference among the different districts using the net flows. According to obtained results the best six districts are: Puente de Vallecas, Aravaca-Moncloa, Hortaleza, Latina, Carabanchel and El Pardo. And, the six worse districts are: Centro, Chamberi, Tetuan, Retiro, Arganzuela and Villa Vallecas.

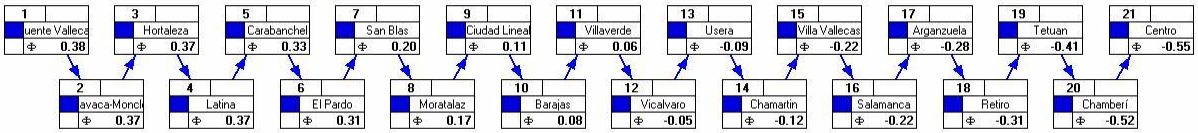

Figure 1: Complete Order (Promethee II) For Objective Criteria

As in the previous case, not incomparabilities when we used the positive and negative flows (that is the reason why the ranking in both cases the ranking is the same). Likewise, Figure 2 shows a graphical representation of the preference among the different districts using net flows. According to these results the best six districts are: Aravaca-Moncloa, Moratalaz, El Pardo, Hortaleza, Salamanca and Retiro. And, the six worse districts are: Villaverde, Centro, Usera, Arganzuela, Carabanchel and Villa Vallecas.

The results are not the same in both cases because the used criteria are different. However, there are some similarities because places such as, Aravaca-Moncloa, El Pardo, Hortaleza are in the best situation using objective and subjective criteria. And places such as, Centro, Arganzuela and Villa Vallecas are in the worse one. It will be interesting to establish the relation of these places with their cost housing or with breathing disorder, however it is not the goal of this paper.

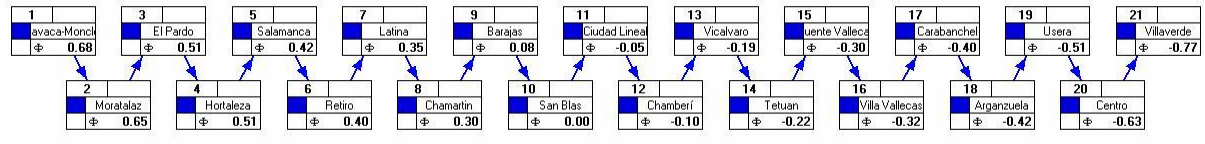

Figure 2: Complete Order (Promethee II) For Subjective Criteria

4. CONCLUSIONS

This work presents the main facts derived from the application of multicriteria methodology to rank the twenty one districts of Madrid city center. This ranking is based on objective and subjective criteria.

According to the obtained results using both types of criteria we can conclude that the ranking among the different districts is not the same. However, in both cases there are places that always are in the best or in the worse positions of the ranking. The best districts have less noise and pollution and the worse have more vandalism, noise and pollution.

That is an important result because the multicriteria classification becomes an useful tool to establish a ranking among the different districts.

ACKNOWLEDGEMENTS

This work has been partially funded by Junta de Comunidades de Castilla-La Mancha,under FEDER research project POII10-0250-6975. We would like to thank the anonymous reviewers for their useful, constructive, and valuable comments, which have undoubtedly improved the manuscript.

AUTHOR INFORMAITON

María-Carmen García-Centeno:
PhD in Economics by CEU San Pablo University and Degree in Economics by University Complutense of Madrid. Lecturer in Statistics at Quantitative Methods Department. Faculty of Business and Economics. CEU San Pablo University. Madrid (Spain). E-mail: garcen@ceu.es
Research Interest: Decision theory, time series analysis, regional analysis, environmental modeling.

Gema Fernández-Avilés:
PhD in Statistics at Statistics Department. Faculty of Social Sciences of Toledo. University of Castilla-La Mancha (Spain). E-mail: gema.faviles@uclm.es; Webpage: http://www.uclm.es/profesorado/gemafaviles/
Research Interest: Spatial statistics, environment and air pollution, geostatistics, education, regional analysis, decision theory and tourism.

REFERENCES

1. Behzadian, M., R.B. Kazemzadeh, A. Albadvi and M. Aghdasi (2010). "PROMETHEE: A comprehensive literature review on methodologies and applications". European Journal of Operational Research.
2. Brans, J.P. (1982). "L'ingénierie de la décision: élaboration d'instruments d'aide à la décision. La méthode PROMETHEE.". Presses de l'Université Laval.
3. BRANS, J.P., MARESCHAL, B. and VINCKE, P.H. (1984). "PROMETHEE: a new family of outranking methods in multicriteria analysis", in J.P BRANS (ed.), *Operational Research'84*, North-Holland, pp. 477-490.
4. Brans, J.P., and P. Vincke (1985). "A preference ranking organisation method: The PROMETHEE method for MCDM". Management Science.
5. Brans, J.P. and Vincke, P.H. (1985). "A preference ranking organization method, the PROMETHEE method" Management Science, 31, pp. 647-656.
6. Goumans, M. and Lygerou, V. (2000). "An extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation projects". European Journal of Operational Research, 123:3, 606-613.
7. Mackay D, Haw S, Ayres J.G., Fischbacher C, Pell J.P. (2010). "Impact of comprehensive, smoke-free legislation on the incidence of childhood asthma". NEJM 2010;3 (63), 1139-1145.