Using Outranking Methods for Optimum Setting of Air Pollution Monitoring Stations

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Introduction

In recent years, increasing population, vehicles and industrial growth have caused air pollution that is initiated many environmental problems and damaged public health. In Tehran metropolis, increasing machine life and human activities on one hand and extreme topographic conditions and natural factors on the other hand has led the city to be the most polluted city of the world. Due to the necessity of preventing and reducing risks of air pollution, acquiring good knowledge of various aspects of this issue is very important.

To check the air quality in different regions, pollution data collected in air pollution stations are required. Air pollution data are needed for studies and decisions about reducing and controlling it. According to the construction of new stations, the precise locating of them is very important. For better and more realistic monitoring of air pollution, the stations must be distributed exactly and evenly. Thus, one of the important considerations in implementing an air pollution control system is selecting the suitable locations for stations.

To determine the appropriate places for the construction of new stations, appropriate measures and models are specified. WSM (Weighted Sum Method), ELECTRE (Elimination and Choice Translating Reality) and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) are three popular models of decision making methods.

In this paper, these 3 methods are used to optimally locate air pollution stations. For this purpose, 20 new locations were initially proposed in Tehran. Thereafter, governing factors layer, such as population density, distance to nearby stations, distance to trees, building walls and streets, are prepared. Priorities of stations are estimated based on the three methods. Thus, to provide a unique ranking for the methods, the triple consolidating methods (simple average, Borda and Copland) were exercised. Finally, to compare the validity of results, air quality maps were generated.

Materials and methods

- **MCDM methods**

Multi-Criteria Decision Making (MCDM) approaches assume that the decision maker’s preferences are made perfectly explicit, so that the only thing left to do is to consider a well-formulated mathematical model.

Outranking methods as a branch of MCDM models for the accurate modeling of real world, define outranking relations based on pair-wise comparisons. Among the various methods that have been presented in the form of outranking methods, ELECTRE and PROMETHEE are used in a wide range of different applications in the world.

In this paper, ELECTRE and PROMETHEE are used and compared with WSM that is the most commonly used method.

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ELECTRE was developed by Bernard Roy in the 1960s as a practical decision making tool and has found vast applications in engineering decision making problems. The method performs pair-wise comparisons among alternatives for each one of the attributes separately to establish outranking relationships between the alternatives.

Preferences in ELECTRE methods are modelled by using binary outranking relations, S, whose meaning is "at least as good as". Construction of an outranking relation is based on two major concepts:

- Concordance. For an outranking aSb to be validated, a sufficient majority of criteria should be in favor of this assertion.
- Non-discordance. When the concordance condition holds, none of the criteria in the minority should oppose too strongly to the assertion aSb.

The PROMETHEE method presented by Brans et al. in the 1984s is an iterative multiple criteria decision making technique designed to handle qualitative and discrete alternatives. This method is a quite simple ranking method in conception and application. This method uses the outranking principle to rank the alternatives, combined with the ease of use and decreased complexity. It performs a pair-wise comparison of alternatives in order to rank them with respect to a number of criteria. It is well adapted to problems where a finite number of alternatives are to be ranked considering several, sometimes conflicting criteria.

The additional information requested to run PROMETHEE is particularly clear and understandable by both the analysts and the decision-makers. It consists of:

- Information between the criteria;
- Information within each criterion.

PROMETHEE and ELECTRE methods have been extended and developed to several methods. Different PROMETHEE and ELECTRE methods may be different in how they define the outranking relations between alternatives and how they apply these relations to get the final ranking of the alternatives. In this study, among the various models of PROMETHEE and ELECTRE methods, ELECTRE III and PROMETHEE II were chosen.

In ELECTRE III the outranking relation can be interpreted as a fuzzy relation. The construction of this relation requires the definition of a credibility index. Furthermore, PROMETHEE II consists of the complete ranking. It is often the case that the decision-maker requests a complete ranking. The net outranking flow can then be considered.

The WSM is the most commonly used method, especially in single dimensional problems. The total value of each alternative is equal to the sum of products of criteria weight and attributes data. The maximum is the best scheme. The method is simple and easy to use. Difficulty with this method emerges when it is applied to multi dimensional decision making problems. In combining different dimensions, and consequently different units, the additive utility assumption is violated.

- **Air monitoring station criteria**

  Air pollution in Tehran under the influence of several factors such as topography, climate, population, transportation network and is the industry. Major air pollutants are carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM10) and ozone (O_3).

  Summaries of air monitoring station criteria are presented by Environmental Protection Agency base on these air pollutants, and the distance from trees, building walls and streets were considered. Moreover, some other researchers have been stated other criteria for locating these stations, such as population density, traffic, balanced distribution of stations in regional areas, etc.

- **Integrative decision process**

  In the integrative decision process, the alternatives ranking are ordered in different decision methods (in this research ELECTRE III, PROMETHEE II and WSM were chosen). If all alternatives ranking orders in several decision-making methods are consistent, the decision process is ended. Otherwise, the sequencing results are consolidated in three methods, simple average, Borda and Copland. When the three results are not the same, the consolidation is needed again.

Otherwise, the decision process ends and the best scheme from the alternatives with respect to each attribute are selected. The decision-making method is vital to the sequencing of the alternatives in MCDM, which is also focused in this paper.

Conclusions

In this research, the study area was Tehran city with 17 air pollution stations. Three methods, namely PROMETHEE II, ELECTRE III and WSM are used to optimally locate air pollution stations. For this purpose, 20 new locations were initially proposed in Tehran. These locations are chosen based on the previous studies and area conditions.

Afterwards, Governing factors such as population density, distance to nearby stations, distance to trees, building walls and streets, are identified. Priorities of stations are estimated based on those three methods and to provide unique ranking, the triple consolidating methods (simple average, Borda and Copland) were used. In our case, the unique ranking was performed in the second iteration.

The validity of results is computed by available air quality maps for carbon monoxide air pollutant. Results indicate the optimality of PROMETHEE and triple consolidating methods (about 82%) versus other methods. The results also show the immediate need for constructing new stations in the vicinity of Basij, Fath, Shahid Araqi, Yadegar-e-Emam and Tehran-Varamin highways.

To continue working in this area, including other criteria such as traffic volume and land use for the location of air pollution measurement stations and using other MCDM methods such as TOPSIS and VIKOR, and also comparing the results with other researchers are suggested.

Also, more accurate selection of 20 primary stations is needed. One of the solutions proposed by researchers in this field is using genetic algorithm and PROMETHEE method. In other words, in the combination of approaches, the whole area is investigated by the genetic algorithm and appropriate options are determined. Thereafter, the best option is founded by PROMETHEE method among these options.

Key words

Air pollution station, Consolidating methods, Multi criteria decision making methods, Air Quality Index (AQI), locating