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Designing Strategic Environmental Decision-Making Model Based on Positioning Assessment of Industrial Towns Utilizing SMCE, TOPSIS and SAW (Case Study: Industrial Towns of Yazd Province)

B.Maghsoudlou, J.Nouri, L.Ebrahimi

Abstract

Among the various parameters considered in the study for justifying the establishment of industrial towns, site selection is one of the most important parameters which according to it will reduce costs and success industrial units. Integration of multiple factors and constraints and considering them together and making correct decisions on the environment, due to its high complexity, necessarily requires the use of various Multi Criteria Decision Making (MCDM) techniques. In this context, the main issue of article has been positioning assessment of new industrial towns in Yazd province and strategic environmental decision-making model planning with utilizing integrated approaches SMCE, TOPSIS and SAW. The main objective of this article has been strategic environmental decision making logic planning based on positioning assessment of industrial towns with integrated utilizing of SMCE, TOPSIS and SAW approaches. In order to achieve this goal, at the first, researches and experiences at national and international levels, has been studied. Then with use of the Delphi questionnaire and Expert Choice software, important constraints and factors, have been selected and the relevant maps were prepared for entering to SMCE model. To evaluate the questionnaire validity and reliability, SPSS software was used. Then the constraints and factors maps were entered to SMCE model in ILWIS software. Constraints and factors have been standardized and the weighting factors were performed using questionnaires results, outputs of Expert Choice software and expert opinions. Then in the priority map, four priorities were considered and the first priority received score of 0.68-0.91. In the next step, selected positioning options by SMCE model entered to TOPSIS and SAW models for weighting and final prioritization and applying qualitative and uncertainty criteria in positioning assessment. Then the based on its results, was performed the final prioritization of Yazd province industrial towns positioning assessment. Finally, it was suggested that according to the high efficiency of SMCE, TOPSIS and SAW models, the models can apply in other development plans positioning assessment including industrial towns.

Key words: Positioning Assessment of Industrial Towns, Delphi Questionnaire, Spatial Multi Criteria Evaluation (SMCE) Model, Technique for Order- Preference by Similarity to Ideal Solution (TOPSIS) Model, Simple Additive Weighting (SAW) Model

Introduction

Nowadays, natural resources and environmental issues were considered as important matter and environment protection organization established some limitations for sustainable development. These limitations caused decision making agents to choose appropriate locations which would cause least environmental damages (Karbasi et al., 2004). Location and positioning of industrial areas around the cities was accounted as key factor in regional planning and negative social, economic and environmental impacts and consequences in these areas must be considered in regional development planning. Suitable location for positioning of industries has encountered with so many factors, so that economic, social and environmental impacts of environmentally sustainable industries must be considered simultaneously (Ahmadi Zadeh and Haji Zadeh, 2012). Therefore, appropriate positioning of industries establishment, has significant importance in management decisions. Since inappropriate positioning not only has no economic and social profits, but will cause catastrophic environmental problems. In recent years and by increasing knowledge, efficient criteria for scientific locating of industries were developed from various aspects and accompanied with decreasing environmental problems (Al-Sheikh et al., 2009). Therefore since positioning is multi-criteria decision which affects various indexes in order to decision making. It seems that use of multi-criteria decision making methods could be effective in decision making process and preparing optimum pattern for positioning of new industrial towns from environmental management viewpoint. Accordingly, spatial evaluation of new industrial towns of Yazd province using Spatial Multi Criteria Evaluation Strategies (SMCE), Technique for Order- Preference by Similarity to Ideal Solution (TOPSIS) and Simple Additive Weighting (SAW) which are Multiple Attribute Decision Making (MADM) - based methods, was aimed in the present study. Mentioned methods by simplifying definition of decision making strategies and facilitation of spatial processing, could be used in various ways for different spatial decision

making issues (Rajabi et al., 2011).Shahabi (2011) studied earthquake risk zoning using multi-criteria spatial analysis method with the aim of zoning earthquake occurring in Kordestan province. Results showed that in the studied area, western strip was located in an area with high risk, central strip in moderate risk and eastern strip in low risk area (shahabi et al., 2011).Savitha and Chandrasekar (2011) studied reliable network selection for heterogeneous wireless networks using SAW and TOPSIS algorithms with the aim of selection of the best network from available visiting networks (VTS) in order to continued communication with customer. They concentrated mainly on delivery decision making step in order to decreasing delay in delivery processing and thus utilized SAW and TOPSIS algorithms (Savitha and Chandrasekar, 2011). Also, Kheir Khah Zarkesh et al. (2011) evaluated ecological and creature capacity for ecotourism based on multi criteria spatial evaluation method with the aim of studying the capabilities of SMCE method for analyzing proportion of land for ecotourism in Do-hezar and Se-hezar hunt-barred area of Bless Kouh. Results showed that in addition to compatibility with current conditions, appropriate decision making to land allocating to different land uses were allowed (Kherikhah Zarkesh, 2011).

Methods and Materials

Studied area

Having regard to requirements presented by Yazd province industrial towns corporation and results of studies conducted in necessity of creating industrial towns, currently Zarch, Nodoushan, Behabad and Harat areas located in Yazd, Sadough, Behabad and Khatam towns requires industrial towns. So, study area was located in 29°35 to 33°23′ N latitude and 52°50′ to 56°39′ E altitude by 74650 km2 area and includes least appropriate natural lands in Iran central plateau. Figure 1 shows study area limits of spatial evaluation of Yazd province industrial towns in Iran and Yazd province. Study area by 6 semi-active faults, has semi- desert soil without enough biological activity, lack of moisture in soil profile, intensive undulations of soil moisture, erosion and has gravels in more than 20cm soil depth. Various vegetation covers of Yazd province includes forests and pastures (Yazd province natural resources organization, 2013). According to studies. Currently, protected areas of Bafgh Mountain and Shadi garden of Khatam, wild life habitat of Borouieh in Khatam and hunt-barred areas of Ariz in Bafgh and Shadi Garden in Khatam town were located in studied area (Yazd province natural resources organization, 2013). In the studied area, pastures have greatest proportion and residential areas have least proportion. Generally, environmental problems of studied area include: lack of comprehensive investigations and definite environmental status in regard to contaminant industries and resources, little supervision on industries in studied area in terms of environmental issues, high contamination of some of industries such as brick kilns, sand factories and heavy and light vehicles as well as atmosphere reversing phenomena and increasing of contamination rate specially in winter nights (Pooyan Sabz Kavir consulting engineering corporation, 2012).

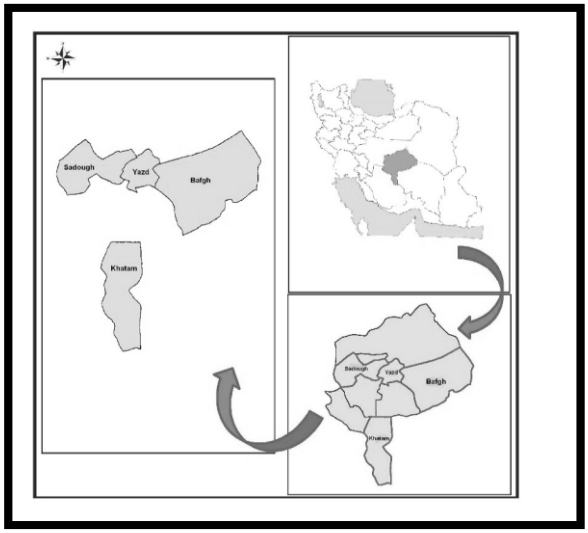


Fig. 1. Location of studied area of spatial evaluation of Yazd province industrial towns in Iran and Yazd Province.

Methodology

In order to recognition and screening the effective criteria in positioning of industrial towns, face to face interview with experts was used via designation, completion and analyzing Delphi questionnaires. Designation of questionnaire and selection of criteria and sub criteria was conducted using designer and analyzer opinions including researcher, supervisor professors according to previous experiences. Delphi questionnaires gave to 33 industrial environmental and urban and regional planning activities associated experts. In order to studying the reliability of questionnaires, Cronbakh- alpha method and SPSS software were used. Having regard to the aim of study was to spatial evaluation and identifying and ranking of the best position of establishing of industrial towns, thus in order to selection of establishment of industrial towns, in addition to SCME, compensative models such as SAW and TOPSIS were used. In the following sections these methods briefly illustrated.

SCME is the multi-criteria decision making model of spatial data. Many options could be prepared and evaluated. This method is useful for analyzing the effects of land use planning and regional development. In studying the positioning of modern industries, this model was used for locating of proper sites using ILWIS program. This computer based program, locating type is multi criteria decision making methods and allows Geographical Information Systems (GIS) to analyzing data and decision making. This method removes limitations which is existed in GIS in huddling of layers number (Nouri et al., 2007).TOPSIS model firstly proposed by Hwang and Yoon (1981) and is one of the best multi criteria decision making models and extensively was used. In this method, the 'm' number of options was evaluated with 'n' index (Mo'meni and Sharifi Salim, 2011). In this method, selected option must have least distance from ideal solution and simultaneously was far from negative ideal solution. Problem solving using this method requires six steps: 1) quantification and making non-dimensional of decision making matrix, 2) acquiring non-dimensional leveled matrix, 3) determination of positive and negative ideal solution, 4) acquiring distances of each option to positive and negative ideals, 5) determination of relative proximity to ideal solution and 6) ranking the options (Asghar pour 2010; Mo'meni, 2006). Therefore, prioritizing of final options of spatial evaluation of Yazd province industrial towns was conducted by TOPSIS and MCDM engine software. SAW model is the oldest and most simple multi criteria decision making method. This method includes scoring method. In this subgroup, it is tried to evaluate the desirability function per each option and so, option having highest desirability would be selected. Therefore, the problem in this subgroup is how to evaluate the desirability function. In order to comparison, this method requires similar indexes and/or un-dimensioned measurements from these indexes. Using of this method is appropriate in cases in which exchangeable rate among indexes was constant and equal to unit (Asghar pour, 2010). Conducting steps are include: quantifying decision making matrix, making linear un-dimensioned amounts of decision making matrix, un-dimensioned matrix coefficient at indexes weights and choosing the best option (Mo'meni, 2006). According to above, prioritizing of final options of spatial evaluation of Yazd province industrial towns, in uncertainty cases, was conducted using SAW model.

Results

In the present study, in order to analyzing questionnaires and calculating mean data, whole responses were entered in SPSS software and based on them, mean of responses were determined. Prioritizing results and weighing of effective criteria in positioning of industrial towns in Expert Choice software and prioritizing of secondary criteria proportion to target showed that highest weight was associated to air pollution and following that was related to water pollution. The importance of these indexes is due to various pollutions of industrial town which the main pollutions are air and water pollution. Incompatibility rate was calculated as 0.09 indicating low error (due to amount less than 0.1). in order to spatial evaluation of Yazd province industrial towns using SMCE model, three factors including physical, ecological and human factors and constraints including distance from surface water sources, distance from groundwater sources, distance from urban areas, distance from rural areas and land use were considered. After selection of effective indexes and preparing maps which can be used in the model, index tree was prepared. Then limitations and factors were standardized using various procedures such as descriptive table of the map, linear direct function, linear compound function and non-linear and indirect cost function. Then, factors and limitations weighing was conducted using direct and paired comparisons methods. Figures 2, show tree-branch model of spatial evaluation of Yazd province industrial towns and index tree of spatial evaluation in SMCE medium.

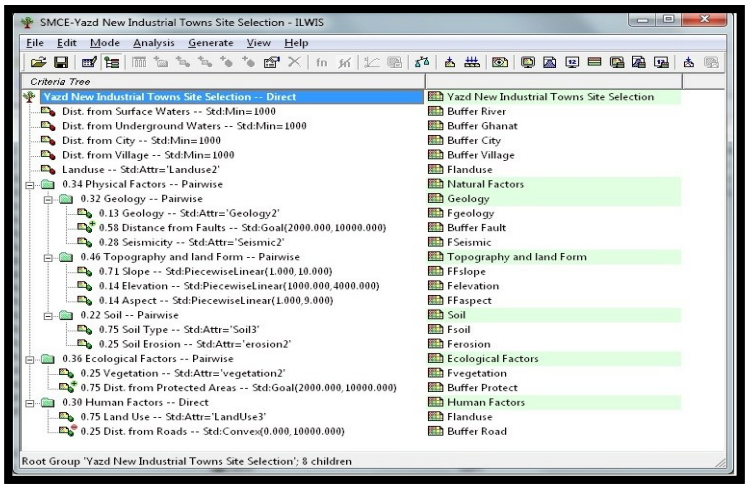


Fig. 2. Index tree of spatial evaluation of Yazd province industrial towns in SMCE medium

Finally, compound index map was yielded. Then this map was divided into four priorities which according to that prioritizing of spatial options of Yazd province industrial towns were presented as follow.

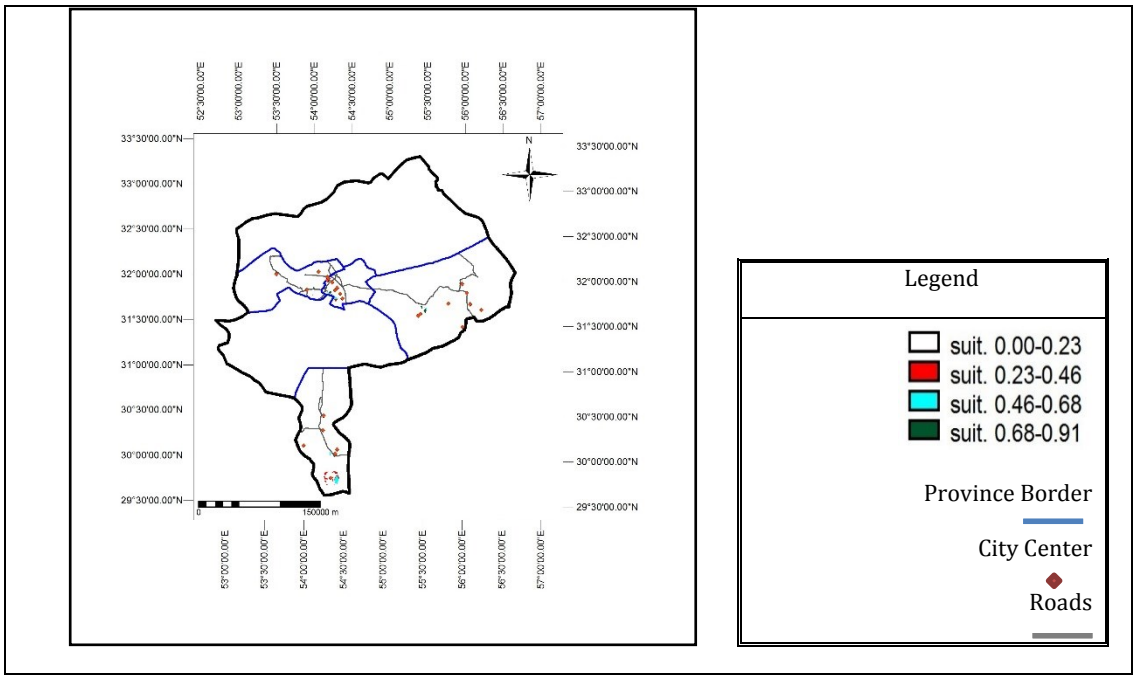
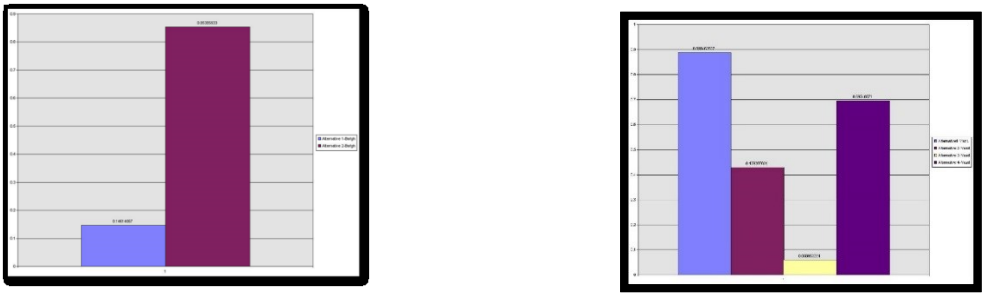


Fig. 3. Prioritizing map of spatial options of Yazd province industrial towns

In Figure 3, dark-green areas are first spatial priority and have greater value (0.68-0.91) for establishing industrial town and occupied 3050 ha area. Also, areas having light-blue color with 0.46-0.68 value have second priority with 6000 ha and areas with red color by 0.23- 0.46 value amount, were the third priority and occupied 5450 ha area. Areas having zero or near the zero value (0-0.23) by 1334025 ha placed in last priority rank.
Then, areas with first spatial priority in different towns were selected and weighed in TOPSIS and SAW models for final prioritizing. Since SMCE is a semi-structured model and some of effective indexes in positioning of industrial towns lacking of digital layers were not considered in decision making, prioritizing of selected proper spatial options by SMCE model were weighed and prioritized TOPSIS model. It should be noted that in this section, only spatial options of Yazd and Bafgh towns were studied, since Sadough and Khatam towns just have one spatial option having first priority. In order to selecting proper indexes, effective indexes by lack of digital layers were considered in spatial evaluation of industrial towns and finally four indexes including dominant wind direction, background environmental pollution, occupation and requirement to new industrial towns were selected. Above mentioned indexes are qualitative and must be quantified. Therefore, using bipolar distance scale, qualitative indexes were converted to quantitative ones. In order to determination of weight of decision making indexes. Expert Choice software was used and so weights are obtained as follow, respectively: 0.185, 0.626, 0.117 and 0.072. Then indexes and options were entered into software. Figure 4 shows prioritizing of spatial options of Yazd and Bafgh industrial towns in TOPSIS software which according to Fig. 6, in Yazd town option No. 1 by weight value of 0.88 is in first priority and options No. 4, 2 and 3 by 0.43, 0.06 and 0.69 weight values, respectively, placed in following priorities. In Bafgh town, option No. 2 by 0.85 values was located in first priority and option No. 1 by 0.15 weight value was in second priority. In order to assessing the accuracy of priorities in TOPSIS software, prioritizing process of spatial options of Yazd industrial towns conducted by TOPSIS-MCDM engine software as well which final weights were equal to final weights acquired in TOPSIS software.



Bafgh town Yazd town

Fig. 4. Prioritizing of spatial options of Yazd province industrial towns

Since SMCE is a semi-structured model and some of effective indexes in positioning of industrial towns lacking of digital layers were not considered in decision making, prioritizing of selected proper spatial options by SMCE model were weighed and prioritized SAW model. In order to selecting proper indexes, effective indexes having lack of uncertainties were considered in spatial evaluation of industrial towns and finally three indexes including vegetation cover, background environmental pollution and land use were selected. Above mentioned indexes are qualitative and must be quantified. Therefore, using bipolar distance scale, qualitative indexes were converted to quantitative ones. In order to determination of weight of decision making indexes. Expert Choice software was used and so weights are obtained as follow, respectively: 0.309, 0.582 and 0.109. Then indexes and options were entered into software. Figure 6 shows prioritizing of spatial options of Yazd and Bafgh industrial towns which according to prioritizing results with indexes having lack of uncertainties in Yazd town, option No. 1 by weight value of 0.86 is in first priority and options No. 4, 2 and 3 by 0.81, 0.69 and 0.29 weight values, respectively, placed in following priorities. In Bafgh town, option No. 1 by value score of 1 compared to option No. 2 by value score of 0.95 was located in first priority.

Discussion and Conclusion

Results from prioritizing of spatial options of Yazd province industrial towns using SMCE model indicate that areas with 0-0.23 value (fourth priority) by 1334025 ha, have the greatest area in the studied range and areas in first priority and highest value (0.68-0.91) for establishing industrial towns, occupied just 3050 ha of the area. This means that great part of studied area has the low capacity for establishing industrial town. Also, results of spatial evaluation by SMCE model show that among studied towns, Khatam town by 11 spatial option (1 zone by first priority, 2 zones by second priority and 8 zones by third priority) appropriate for establishing industrial town, has the greatest ability for creating industrial town and Sadough town by three spatial option (1 zone by first priority, 1 zone by second priority and 1 zone by third priority) has the lowest ability for creating industrial town. Based on results, options having first spatial priority, located in proximity of accessing roads and population centers which made possible of ease of access. It should be noted in Sadough and Khatam towns; only 1 spatial option was identified as first priority which both of them was selected as final options for establishing industrial tows. While, spatial options selected for Yazd and Bafgh towns were entered to TOPSIS and SAW models for weighing and prioritizing. Since SMCE is a semi-structured model and some of effective indexes in positioning of industrial towns lacking of digital layers were not considered in decision making. Therefore prioritizing of appropriate spatial options selected by SMCE in Yazd and Bafgh towns were weighed and prioritized by TOPSIS as well. Results showed that option No. 1 was in first priority and options No. 4, 2 and 3 were placed in following priorities. Since No. 1 was located in against of dominant wind direction proportion to population centers and in area with low environmental pollution. Since above mentioned two indexes had greatest score in prioritizing process (0.185 and 0.626, respectively).Results from prioritizing of spatial options of Bafgh province industrial towns using TOPSIS model indicate that option No. 2 by 0.85 value was located in first priority and option No. 1 by 0.15 weight value was in second priority. No. 2 is located against dominant wind direction proportion to population centers. Therefore, No. 2 having regard to great score of dominant wind direction (0.185), located in first priority and was selected as the best spatial option for industrial town in Bafgh town. It should be noted that results were confirmed by TOPSIS-MCDM engine software. Since SMCE is a semi-structured model and some of effective indexes in positioning of industrial towns lacking of digital layers were not considered in decision making, prioritizing of selected proper spatial options by SMCE model in Yazd and Bafgh towns, were weighed and prioritized by TOPSIS model. Considering to effective indexes having lack of uncertainties in spatial evaluation of industrial towns including vegetation cover, background environmental pollution and land use in Yazd town option No. 1 is in first priority and options No. 4, 2 and 3 placed in following priorities. Since No. 1 was located in low density pastures and little environmental pollution and also is located in strongly eroded and inferior lands. Thus considering to great score of environmental pollution index (0.582) and vegetation cover (1), was place in first priority. Therefore based on prioritizing process of SAW model, option No. 1 was selected as the best spatial option for establishing industrial town. In Yazd town, option No. 1 was superior to No. 2. Since both options were in similar status in terms of vegetation cover and background environmental pollutions, No. 1 considering landing use, located in strongly eroded and poor lands, while option No. 2 located in sand dunes. Therefore based on prioritizing by SAW model, option No. 1, was selected as the best spatial option in Bafgh town. Based on results of prioritizing by TOPSIS and SAW models, option No. 1 was selected as the best option, but results of TOPSIS and SAW for Bafgh industrial towns were not consistent. So, considering to more importance of dominant wind direction (0.22) compared to land use (0.21) (based on weighing in Expert Choice software), option No. 2 was selected as the best spatial option in Bafgh town.

Totally comparative comparisons of abilities and identifying the decision making levels of SMCE, TOPSIS and SAW models in spatial evaluation of industrial towns showed that:

- Conversion of digital and descriptive information to visible maps in SMCE is one of the important properties of this method which made possible final decision making by high accuracy and could have very effective in spatial evaluation of industrial towns.
- Sensitivity analysis of decision making, ability to prioritizing of infinite options based on infinite indexes and least deficit in options prioritizing are of the properties of TOPSIS model which made in widely used among multi- criteria decision making models.

- Simplicity and ease of use and obtaining to more realistic results in analyzing and prioritizing of the effects are of important properties of SAW model.
- Comparison and prioritizing of TOPSIS and SAW is impossible. Since these methods are different in utilization and principally could not be compared.

Finally, according to present study and identifying the abilities and constraints of three mentioned methods, following action plans were recommended:

- Appropriate criteria, regulations and standards for spatial evaluation of industrial towns must be prepared based of regulations and criteria of establishing of industries and environment according to three main viewpoints including economic, applied and sustainable development (sustainable development theory), for mediating problems resulted from industries and removing environmental pollutions resulted from their operations by corporation of small industries and Iran's industrial towns and national environmental organization.
- SMCE model must be developed and evaluated for spatial evaluation developing projects according to its great potential to solving complex and diverse problems and its great effectiveness due to high accuracy final decision making specially in analyzing the effects of land use planning, validating development options in evaluating environmental effects, positioning of proper lands for establishing of industrial towns, evaluation of ecological capacity, validating and positioning of industrial wastes landfill, positioning of home wastes landfills, positioning and environmental decision making of new cities, evaluating the air pollution reducing technologies in power plants and so on. so, cooperation of environmental protection organization, industry, mine and trade organization, national organization of forests, rangelands and watersheds, organization of municipalities and whole administrative institutes in developing projects in order to establishing SMCE model in positioning issues of projects must be considered.
- TOPSIS model must be developed and evaluated for weighing of effective criteria in environmental decision making, developmental actions according to accurate and deep investigation of internal and external (environmental) factors effective on environment considering to its wide application among multi- criteria decision making models due to decision making sensitivity analyzing, ability to prioritizing of infinite option based on infinite deficit in options ranking. For this purpose, cooperation of environmental protection organization and other policy maker organizations for developmental actions of establishing TOPSIS model in developmental actions of environmental decision making processes must be considered.
- SAW decision making model for ranking of effective indexes in environmental decision making in developmental actions must be evaluated and developed considering to acquiring more realistic results in analyzing and prioritizing criteria and effects. For this purpose, cooperation of environmental protection organization and other policy maker organizations for developmental actions of establishing SAW model in developmental actions of environmental decision making processes must be considered .
- Joint utilization of SMCE, TOPSIS and SAW strategies in spatial evaluation of developmental projects in order to use of capabilities and removing their limitations and potential tool in environmental management in comprehensive and accurate decision making must be considered by developmental actions policy-maker organizations.
- Specific questionnaires such as Delphi must be appropriately used for acquiring opinions and judgments of a group of experts in order to facilitating problem solving, planning and decision making.
- Considering to importance of questionnaires results in selection of effective factors in positioning developmental projects, choosing more extensive questions using opinions of different groups of designers and analyzers as well as experienced experts to responding questions (target group) such as administrative, professional experts of policy-maker organizations, academic professors and experts in environmental issues in public and private sections in using SMCE, TOPSIS and SAW models could result in more powerful results.
- considering to great importance of information layers in multi criteria decision making methods specially SMCE and having regard to specific environmental conditions of each index and changeability of their importance, experts should determine these parameters for each area.
- SMCE model could be used as multi criteria decision making model, since it has scoring ability based on phasic logic and like other methods like AHP, has weighing ability. But, SMCE model due to not considering of uncertainties could not be located in compatibility group.

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B.Maghsoudlou, Department of Environment, Maybod Branch, Islamic Azad University, Maybod, Iran
Corresponding Author E-mail: bizhan.maghsoudlou@gmail.com
J.Nouri, Department of Environmental Management, Science and Research Branch, Islamic Azad University, Tehran, Iran
L.Ebrahimi, Department of Environmental Management, Science and Research Branch, Islamic Azad University, Tehran, Iran