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A military airport location selection by AHP integrated PROMETHEE and VIKOR methods

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ABSTRACT

This paper presents a location selection problem for a military airport using multiple criteria decision making methods. A real-world decision problem is presented and the decision criteria to evaluate alternative locations are specified. The objective is to identify the best location among candidate locations. Nine main criteria and thirty-three sub-criteria are identified by taking into account not only requirements for a military airport such as climate, geography, infrastructure, security, and transportation but also its environmental and social effects. The criteria weights are determined using AHP. Ranking and selection processes of four alternatives are carried out using PROMETHEE and VIKOR methods. Furthermore, the results of PROMETHEE and VIKOR methods are compared with the results of COPRAS, MAIRCA and MABAC methods. All methods suggest the same alternative as the best and produce the same results on the rankings of the location alternatives. One-way sensitivity analysis is carried out on the main criteria weights for all methods. Statistically significant correlations are observed between the rankings of the methods. Therefore, it is concluded that PROMETHEE, VIKOR, COPRAS, MAIRCA and MABAC methods can be successfully used for location selection problems and in general, for other types of multi-criteria decision problems with finite number of alternatives.

1. Introduction

Location selection among a set of alternatives along with several conflicting criteria is a multiple criteria decision making (MCDM) problem. Satisfying all criteria simultaneously in selecting from a finite number of alternatives is not possible when criteria are in conflict and in such cases, MCDM methods provide a compromise solution to the problem. AHP (Analytic Hierarchy Process), PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations) and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) are MCDM methods chosen to use in this study.

The objective of this study is to select the most appropriate location among alternatives for a military airport in Turkey. There are four location alternatives which are named A, B, C, and D due to confidentiality. Nine main criteria and thirty-three sub-criteria are determined through reviewing the literature and consulting three experts who are the decision makers of the location selection process of the military airport. In addition to the requirements for a military airport, such as climate, geography, infrastructure, security, and transportation, the environmental effects of the military airport and its social effects on residents living in the region are also taken into account in determining the criteria. Operations of airports have environmental effects on the population, animals, plants, crops, water, land, etc. by causing pollution and noise (Grampella et al., 2017). Not only operational and financial

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performance measures but also environmental and social issues associated with the airport activities are in the focus of airport performance measurement due to the interests of different stakeholders, such as customers, local governments, regulators and community (Bezerra and Gomes, 2016). Endrizalová and Gandi (2016) evaluate negative environmental effects of airport operations by categories of noise, emissions, energy consumption, water and soil pollution, and waste management.

MCDM methods help decision makers solve complex decision problems involving conflicting criteria in a systematic and consistent way. Mardani et al. (2015) show that use of MCDM methods has significant growth in the field of transportation systems. In this study, AHP is used to determine the weights in the hierarchy of criteria. Two different types of MCDM methods, PROMETHEE as an outranking method and VIKOR as a compromise ranking method are used for ranking and selection process in order to be confident in selecting the best alternative. Another reason for using these methods is their successful applications to the MCDM problems in the literature. AHP is integrated with both methods by using the criteria weights derived by it.

AHP, which was proposed by Saaty (1977) based on a hierarchical structure and pairwise comparisons, has been extensively applied in all research areas including environmental science and technology in the recent years (Emrouznejad and Marra, 2017; Cegan et al., 2017). The wide use of AHP can be attributed to its easy applicability to large-scale and complex decision problems involving multiple criteria and subjective evaluations as well as its successful integration with other MCDM methods. Ballis (2003) uses both engineering judgment and AHP approaches for a new airport site selection based on the criteria of land use, existence of historical or archaeological resources, wind characteristics, cost of airport construction and earthworks, and socio-economic impacts due to expropriation of land and buildings; and finds the same site as the best alternative by both approaches.

Brans developed PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking); Brans and Mareschal developed PROMETHEE III (ranking based on intervals), PROMETHEE IV (continuous set of feasible solutions) and the visual interactive module GAIA (Geometrical Analysis for Interactive Aid) to support the PROMETHEE methodology and further suggested two extensions PROMETHEE V (multiple criteria decision analysis including segmentation constraints) and PROMETHEE VI (representation of the human brain) (Brans and Mareschal, 2005). Behzadian et al. (2010) provide a comprehensive literature review on PROMETHEE methodologies and applications where the location problems are under the topics of Environmental Management, and Logistics and Transportation. Ishizaka et al. (2013) apply PROMETHEE, Weighted Sum Method and TOPSIS methods to select the location for the construction of a casino in the Greater London region. Curran et al. (2014) use Multi-Attribute Value Theory and PROMETHEE II for determining best locations for US Department of Defense Humanitarian Assistance projects. Kabir and Sumi (2014) utilize integrated Fuzzy AHP and PROMETHEE methods for selection of power substation location. Elevli (2014) applies Fuzzy PROMETHEE for choosing among potential logistics center locations. Kourtit et al. (2014) use AHP with Expert Choice software and the PROMETHEE with D-Sight software and the GAIA (Geometrical Analysis for Interactive Aid) technique for rankings of global cities based on a combined multi-stakeholder-multi-criteria approach. Chen (2015) presents an interval type-2 fuzzy PROMETHEE method and its application to a landfill site selection problem. Joshi et al. (2016) implement PROMETHEE II method for ranking of various locations for hydroelectric power plants.

The literature on VIKOR and Fuzzy VIKOR methods is reviewed by Yazdani and Graeml (2014) for a total of 198 papers with 9 main application areas from 2002 to 2014, by Gul et al. (2016) for a total of 343 papers with 13 main application areas from 1998 to 2015 and by Mardani et al. (2016) for a total of 176 papers with 15 main application areas from 2004 to 2015. Uludag and Deveci (2013) apply Fuzzy VIKOR and Fuzzy TOPSIS methods to a potential city airport location selection problem by evaluating thirty-four sub-criteria under nine main criteria (geographical specifications, climatic conditions, infrastructure conditions, costs, transportation, the possibility of extension, legal restrictions and regulations, potential demand, environmental and social effects) for five location alternatives. Milosevic and Naunovic (2013) apply VIKOR for selecting the most suitable location for a sanitary landfill facility from three alternatives by evaluating thirty-two sub-criteria under five main criteria (hydrogeological criteria, meteorological criteria, spatial criteria, socio-political criteria, and legal and economic criteria) and use fuzzy AHP for determining weighting coefficients of the evaluation criteria. Liu et al. (2014) propose an extended VIKOR method based on the interval 2-tuple linguistic variables to select the best disposal site for municipal solid waste among four alternatives considering four criteria (adjacent land use, climate, road access, and cost). Mokhtarian et al. (2014) propose Interval Valued Fuzzy VIKOR as a reliable method to select a suitable location for digging some pits for municipal wet waste landfill. Gupta et al. (2016) propose an extended VIKOR method using trapezoidal intuitionistic fuzzy numbers and apply it to the plant location selection problem with six criteria (skilled workers, expansion possibility, availability of acquirement material, investment cost, transport facilities, and climate) and three location alternatives. Hariz et al. (2017) perform Geographical Information Systems (GIS) analysis to identify feasible incinerator locations based on economic, environmental and social criteria and then use AHP, VIKOR and PROMETHEE methods to select the best location for a central healthcare waste incinerator.

Since the location selection is a complex multi-criteria decision making problem, various methods are proposed in the literature by the researchers. Kahraman et al. (2017) apply intuitionistic fuzzy Evaluation based on Distance from Average Solution (EDAS) method to the solid waste disposal site selection problem. Bozanic et al. (2016) use fuzzy AHP in weighting the criteria and Multi-Attributive Border Approximation Area Comparison (MABAC) method in ranking alternatives in order to select locations for the preparation of laying-up positions. Gigović et al. (2016) apply a combined model of GIS and multi-criteria techniques where Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) are used for weighting evaluation criteria and MultiAttributive Ideal-Real Comparative Analysis (MAIRCA) method is used for ranking and selecting suitable locations for ammunition depots. Wu et al. (2016) utilize Elimination et Choix Traduisant la Realité-III (ELECTRE-III) in the intuitionistic fuzzy environment for the offshore wind power station site selection. Zavadskas et al. (2015a) apply Weighted Aggregated Sum Product Assessment (WASPAS) method with Single-Valued Neutrosophic Set for sustainable assessment of location alternatives of a waste incineration plant by taking into account the ecological, technological, and urban aspects. Zavadskas et al. (2015b) use a combination