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Railway station site selection using analytical hierarchy process and data envelopment analysis ☆

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ABSTRACT

This paper deals with the problem of finding the optimum site for a railway station for the city of Mashhad, northeast Iran, using the methods of analytical hierarchy process (AHP) and data envelopment analysis (DEA). The paper identifies a four-level hierarchy model for the railway station site-selection problem. The model uses four main criteria: (1) rail-related, (2) passenger services, (3) architecture and urbanism, and (4) economics. In addition, there are 26 subcriteria as well as five (potential) candidates or alternatives. Comparison matrices are used to obtain the local weights and priorities of the railway-station candidates. A DEA model is proposed to determine the optimum site for a railway station. It is shown that the local priorities (or weights) obtained from the AHP can be defined as the multiple outputs of a DEA model for finding the best site for a railway station.

1. Introduction

The aim of a site-selection problem is to find the optimum location that satisfies a number of predetermined selection factors. The process of a site selection typically involves two main stages: *screening* and *evaluating*. The first stage identifies a limited number of candidate sites, from a broad geographical area, taking into account the selection criteria. The second stage includes a careful examination of alternatives to find the most appropriate site (Chang, Parvathinathan, & Breeden, 2008). The second stage is an important issue; for example, in the waste management where the selection of an appropriate solid waste landfill site requires the consideration of multiple alternatives and evaluation criteria (Guiqin, Li, Guoxue, & Lijun, 2009). Choosing the location of a new facility, such as a railway station, subject to multiple criteria is an important decision-making problem for environmental managers. In recent years, several decision-making methods have been proposed for different site-selection applications. For example, Ballis (2003) used the analytical hierarchy process (AHP) for an airport-site selection on the Island of Samothraki, Greece. Also, Guiqin et al. (2009) applied geographical information systems (GIS) and AHP for solving the problem of selecting a landfill site for solid waste in Beijing, China. Similarly, Vahidnia, Alesheikh, and Alimohammadi (2009) suggested a fuzzy AHP method for determining the optimum site for a hospital.

This paper explores the problem of finding the optimum location of a railway station in the city of Mashhad, northeast Iran, using a hierarchy structure. We introduce the railway station site-selection problem as a hierarchy model consisting of four levels, each with its own main criteria. The main criteria are: (1) rail-related, (2) passenger services, (3) architecture and urbanism, and (4) economics. Each of these main criteria is then divided into several subcriteria, giving a total number of 26 subcriteria. In addition, the hierarchy model has five potential railway stations, as candidates or alternatives. We use expert judgment to perform the individual pairwise comparisons in the AHP. Furthermore, we incorporate a data envelopment analysis (DEA) for aggregation of the AHP global priorities. The result indicates that the DEA model is useful for finding global priorities among the potential railway stations. In particular, we conclude that the local priorities (or weights) obtained from the AHP can be defined as the multiple outputs of a DEA model for finding the most suitable site for a railway station.

2. Site selection using AHP

The AHP, initiated by Saaty (1980), is a flexible multicriteria decision-making methodology that transforms a complex problem into a hierarchy with respect to one or more criteria. The AHP method has been used for a wide variety of decision makings in fields such as government, business, industry, healthcare, and

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education (Boroushaki & Malczewski, 2008; Forman & Gass, 2001; Jyrki et al., 2008; Linkov, Satterstrom, Steevens, Ferguson, & Pleus, 2007; Raharjo, Xie, & Brombacher 2009; Saaty, 2008), and also for site-selection problems. For example, Ballis (2003) used the AHP method for an airport-site selection on the Island of Samothraki, Greece, and Korpela, Lehmusvaara, and Nisonen (2007) selected a warehouse operator network using a combination of the AHP and DEA methods. Also, Onut and Soner (2008) used the method for trans-shipment site selection and Rosenberg and Esnard (2008) used a hybrid version for a transit site selection. Furthermore, Hsu, Tsai, and Wu (2009) used the method to analyze tourist choice of destination, Dagdeviren, Yavuz, and Kilinc (2009) to analyze the problem of weapon selection, and Garcia-Cascales and Lamata (2009) to choose a cleaning system for engine maintenance. The AHP method requires the following pairwise comparison matrix, A, which contains the relative weights of the criteria:

$$A = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_i}{w_1} & \frac{w_i}{w_2} & \cdots & \frac{w_i}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix}$$

where w_i is the importance weight of the ith criteria with respect to goal, or the importance weight of the ith subcriteria ($i = 1, \ldots, n$) with respect to criteria and so on. Furthermore, the importance weights can be obtained using the following equation (Saaty, 1980, 2008).

$$Aw = \lambda_{\max} w$$

where, $\lambda_{\max}$ is the maximum eigenvalue of the matrix and $w = (w_1, \ldots, w_n)$ is the corresponding eigenvector of A.

3. Information background

The Khorasan Razavi province is located in northeast Iran. The Mashad railway station is a multi-functional facility located in the centre of the city of Mashhad. This central region is in the vicinity of the eastern and north-eastern railways. In addition, the train stations Neghab and Kashmar, both of which are close to the border between Iran and Turkmenistan, have end stations in the adjacent regions. Because of the position and recreational-religious role of city of Mashhad, there is a great number of activities in the city, many of which depend on the railway. In addition, the Mashhad railway station serves six main lines and eight secondary lines, whose total length inside the station is about 28 km. The station is equipped with four passenger platforms, but these are not sufficient to support the expected increase in the number of passengers and associated rail services that are needed. The Mashhad railway station occupies an area of 175 hectares and is located in a high-density city centre. The railway lines thus conflict with the surrounding urban structures. The Mashhad railway station needs to be improved for several reasons, including the following: (1) the limited capacity of the station building, (2) the small size of the railway fleet (rolling stocks), (3) the lack of a proper infrastructure, (4) the environmental problems such as visual and sound pollution around the station, and (5) an expected increase in the flow of passengers and cargo transferred through the station in the near future.

There are several alternatives in dealing with the expected increase in the number of passengers and the volume of cargo. The first alternative is to develop an entirely new high-capacity station, for which there are two candidates as potential sites. The second alternative is to construct a satellite station adjacent to the present station, for which there are also two candidates as potential sites. The third alternative is to increase the capacity of the existing station. Thus, the main purpose of this study is to find which of these five options should be selected; that is the first alternative (with two potential sites), the second alternative (again with two potential sites), or the third alternative.

3.1. A hierarchy model

Fig. 1 shows a four-level hierarchy model for the railway station site-selection problem in Mashhad.

The first level presents the goal of the problem, which is to find the optimum place of the railway station among potential candidates. As is shown in the second level, the objective of the model is divided into four main criteria, namely rail-related, passenger services, architecture and urbanism, and economics. The third level consists of 26 subcriteria which are related to the main criteria. Also, the five potential stations are given at the final level of the proposed hierarchical model.

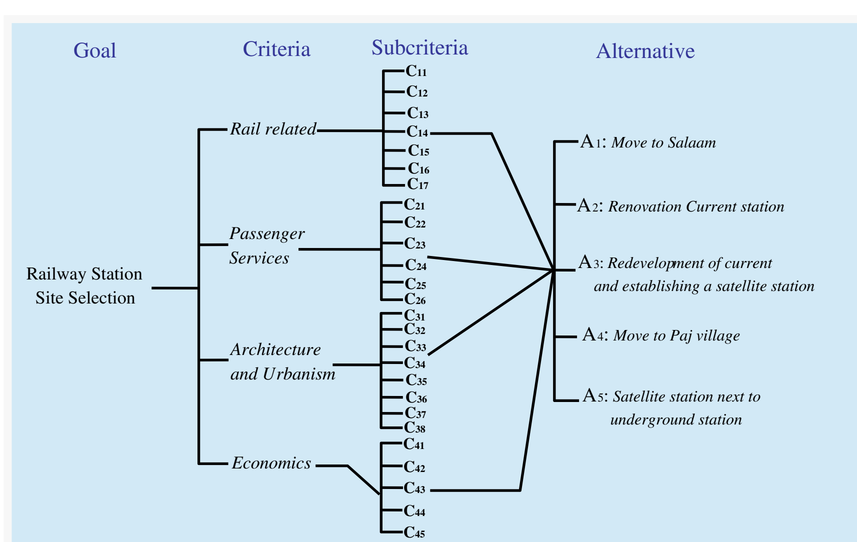

Fig. 1. Hierarchy model for a railway station.