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Decision support for centralizing cargo at a Moroccan airport hub using stochastic multicriteria acceptability analysis

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ABSTRACT

The geographical location of Morocco places it at the heart of important sea, air, rail and motorway transport routes between four continents. In this study we evaluate different alternatives to centralize multimodal cargo at a Moroccan airport hub. The choice depends on different socio-economical criteria, the geographical location, and the environmental impacts. Some of the criteria can be measured quantitatively, while for others only qualitative assessment is feasible. Furthermore, significant uncertainty is present in both the criteria measurements and the preferences. We aided this decision process using Stochastic Multicriteria Acceptability Analysis (SMAA). SMAA is a method that allows the representation of a mixture of different kinds of uncertain, imprecise and partially missing information in a consistent way. The results indicated that two of the alternatives, Benslimane and Casablanca, were superior. As a result of the analysis, the National Airport Authority of Morocco started negotiations with investors to develop the hub at Benslimane.

1. Introduction

The geographical position of Morocco places it at the heart of important sea, air, rail and motorway transport routes between four different continents. Literature works in the USA have shown the strong link between the economic power of urban areas and the air traffic volume (Ivy et al., 1995; Brueckner, 2002). Many authors have highlighted the structure of the local economy in different works. According to these studies a concentration of certain types of economic activities stimulate more air traffic because of their need for contacts and the high tertiary sector; for example, they generate a large volume of air traffic via business travel. Ivy et al. (1995) demonstrated the close relationship between the number of administrative and ancillary jobs and the level of air traffic.

Tangier Med Port has become the largest port on the Mediterranean Sea. The motorway network and rail connections between this port and Casablanca, as well as connections to the airports in Tangiers, Casablanca and Benslimane provide opportunities for the multimodal shipments of goods that enhance this position. In addition, the various free trade agreements available to Morocco (Europe, USA, the Arab Countries) create a platform for the receiving, packaging and shipping of cargo for airlines and major distributors of goods between Asia, America, Africa and Europe.

The main objective of this study is to provide support for the decision on the location of a centralized air cargo hub. The hub will be located at one of the existing airports in Morocco and will serve the multimodal transport of goods between different continents. The decision process is undertaken by the National Airports Authority of Morocco (ONDA) in cooperation with the Civil Aeronautical Department (DAC) and the Air Bases Department (DBA). The actual decision maker (DM) is the CEO of ONDA. ONDA will provide the airport infrastructure for the hub. External investors will manage the commercial development part of the hub. The decision is based on all the elements and results produced by this study. In this process, the decision depends mainly on the marketing strategy of ONDA and its relationship to the potential developers of hub logistics. ONDA needs to justify the validity of the decision process and its conclusions towards the investors. On the basis of this study, ONDA should be in the position to present crucial factors to attract potential investors.

In this study we perform detailed analysis on nine alternative locations. The choice between them depends on different socio-economic criteria, the geographical location, and the environmental impacts, which are measured in terms of six criteria. Since different alternatives have different advantages and disadvantages with respect to different criteria, and different stakeholders may have different opinions on the relative importance of different

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criteria, this problem is a typical multiple criteria decision aiding (MCDA) problem.

We applied Stochastic Multicriteria Acceptability Analysis (SMAA) in this study. For recent real-life MCDA location problems applying different methodologies, see e.g., Feng et al. (2010) and Mateus et al. (2008). The DM considered SMAA suitable, because it can handle flexibly different kinds of incomplete information present in the problem. Some of the criteria were measured quantitatively, while for others only qualitative (ordinal) assessment was feasible. Significant uncertainty or impreciseness was present in the criteria measurements. Furthermore, reliable and up-to-date preference information was not available for all criteria and from all stakeholders. SMAA allows the representation of such a mixture of different kinds of uncertain, imprecise and partially missing information in a consistent way using probability distributions. The analysis is based on a stochastic simulation of the uncertain information and the collecting of statistics on the performance of different alternatives, on the basis of an assumed decision model. Missing preference information can be treated in SMAA with what is called inverse weight space analysis in order to identify the preferences that favor each alternative. In general, the results of the analysis describe the conditions that make each alternative the most preferred one, or give it a particular rank.

The idea of weight space analysis was introduced by Charnetski (1973) and Charnetski and Soland (1978). Their method could handle preference information in the form of linear constraints for the weights, but was restricted to deterministic criteria measurements and an additive utility function. A more versatile approach to handling incomplete preference information is to represent the preferences by suitable distributions. Examples of such methods include the overall compromise criterion method by Bana e Costa (1986), and the stochastic multicriteria acceptability analysis (SMAA) methods. The SMAA methods handle imprecise, partly missing, or conflicting weight information by exploring the weight space in order to describe what weights, if any, make an alternative most preferred. During the analysis, both criteria measurements and weights are constrained by their distributions. Related simulation approaches for analyzing multicriteria problems with different kinds of incomplete information include, for example, those by Stewart (1993, 1995, 1996), Butler et al. (1997), Durbach and Stewart (2008), García et al. (2009) and Jiménez et al. (2009).

Different variants of SMAA exist. In the original SMAA method by Lahdelma et al. (1998) the analysis was performed on the basis of an additive utility or value function and stochastic criteria data to identify for each alternative the weights that made it most preferred. SMAA-2 by Lahdelma and Salminen (2001) generalized the analysis to apply a general utility or value function, to include various kinds of preference information and to consider holistically all ranks. SMAA-3 (Lahdelma and Salminen, 2002) is based on *pseudo-criteria* in the way of the ELECTRE III decision-aid (see, e.g., Roy, 1978, 1996; Vincke, 1992). Instead of a value function, SMAA-D (Lahdelma and Salminen, 2006) applies the efficiency score of Data Envelopment Analysis (DEA). The SMAA-O method (Lahdelma et al., 2003) extended SMAA-2 for treating mixed ordinal (qualitative) and cardinal criteria in a comparable manner. The Ref-SMAA and SMAA-A methods (Lahdelma et al., 2005; Durbach, 2006, 2009a) compare the alternatives by applying Wierzbicki's achievement scalarizing functions. Different ways to represent dependent uncertain criteria are presented in Lahdelma et al. (2006, 2009). Recent developments include SMAA-P (Lahdelma and Salminen, 2009) based on the piecewise linear prospect theory, SMAA-TRI (Tervonen et al., 2009) for sorting problems, based on ELECTRE-TRI (Yu, 1992), and an application of SMAA for descriptive decision analysis (Durbach, 2009b). The efficient implementation and computational efficiency of the SMAA methods have been described in Tervonen and Lahdelma (2007). For a survey on the different SMAA methods and applications, see Tervonen and Figueira (2008). Because the problem at hand contains a mixture of qualitative and quantitative information, we decided to apply the SMAA-O method.

2. Problem description

Centralizing multimodal cargo is very actual issue for Morocco. Although domestic cargo traffic has declined recently, international cargo tonnage has increased (see Appendices A and B). The decline in domestic cargo traffic is caused by several factors, including the annual agricultural crop levels and the level of air cargo tariffs. The average annual growth of international cargo tonnage was only 1.8% during the period 1995–2005; however, over the last five years it increased in volume at the average annual rate of 3.8%.

2.1. Selecting the alternatives

To determine the potential alternative sites for analysis, we first performed a rough analysis of all 16 national and international Moroccan airports listed in Table 1. Both large and small cities can be favorable locations for the air cargo hub. The high competence level and versatile economic structure around larger cities is boosted by the hub. But also small cities can benefit from the strong growth potential of air cargo and from the competition it causes. Other important factors for locating the hub are the con-

Table 1
Preliminary analysis of national and international airports.

Airport	Current traffic	Connectivity by road	Connectivity by rail	Freight potential
Agadir	xx	xx	x	xxx
Al Hoceima	x	x		xx
Benslimane	x	xx		xxx
Casablanca	xxx	xxx	xxx	xxx
Dakhla	x	x		xx
Errachidia	x	x		x
Essaouira	x	xx		x
Fez	xx	xxx	xxx	xx
Laayoune	x			xx
Marrakesh	xx	xxx	xxx	xx
Nador	x	xxx		xx
Ourzazate	x	x		x
Oujda	xx	xx	xx	xx
Rabat	xx	xxx	xxx	xxx
Tangier	xx	xxx	xx	xxx
Tetouan	x	xx		x