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Multi-criteria selection of a deep-water port in the Eastern Baltic Sea

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ABSTRACT

Sea ports play a significant role in the development of a modern economy. The Baltic Sea is an arterial transport corridor between Eastern and Western Europe. There is need to develop a deep-water sea port in the Klaipeda region to satisfy economic needs. This problem involves a multitude of requirements and uncertain conditions that have to be taken into consideration simultaneously. Numerous studies have been designated for the resolution of similar problems by employing multi-criteria as an aid. This paper proposes an integrated multi-criteria decision-making model to solve the problem. The backbone of the proposed model consists of a combination of Analytic Hierarchy (AHP) and Fuzzy Ratio Assessment (ARAS-F) methods. This model is presented as a form of decision aiding that could to be implemented when regarding any specific port or a like site selection.

1. Introduction

International logistics is a problem of crucial importance for the development of a modern world [1]. Critical infrastructures play a significant role in countries due to the essentiality of national security, public safety, socioeconomic security and life style [2]. Infrastructures are very important for integrating EU countries. Scenario planning helps explore how the possible futures may look like and establishing plans to deal with them [3]. Modelling real world problems with crisp values under many conditions is inadequate because human judgement and preference are often ambiguous and cannot be estimated with exact numerical values [4]. Multiple and conflicting criteria including quantitative as well as qualitative can be considered and evaluated during the site selection process [5]. Construction projects are initiated in dynamic environment which result in circumstances of high uncertainty and risks due to accumulation of many interrelated parameters [6]. In actual environmental the stakeholders are often required evaluating the investment strategies according to their own subjective preferences in terms of numerical values from various criteria [7].

Klaipeda is the only ice-free port on the eastern coast of the Baltic Sea. Unfortunately its infrastructural capacity will not be sufficient for further effective activities, not even after fully mastering the existing and reserved port areas. The Port of Klaipeda has problems in handling Baltmax-type ships.

Problems in selecting seaports have been investigated by many researchers. Wiegmans [8] presents the problem faced by deep-sea container carriers regarding container terminal selection. This study reveals that port selection and terminal selection are not the same, when it comes to the criteria for terminal selection, which mainly depend on handling speed, handling costs, reliability and hinterland connections. This analysis concludes that decision-making differs per container carrier, per trade and per port type, thereby implying the irrelevancy of a one size fits all approach.

A number of research approaches have been proposed for solving decision-making problems. Most of these approaches focus on developing quantitative models for dealing with objective data or qualitative models for dealing with subjective ratings.

Meanwhile shipping lines attach great value to often neglected factors, such as feeder connectivity, environmental issues and the total portfolio of a port in addition to the aforementioned criteria.

The major problem faced by port professionals (e.g., port risk managers and port auditors) is the lack of an appropriate methodology and evaluation techniques to support their decisions [9].

Önüt and Soner [10] point out the importance of site selection as an issue. The complexity of a system involved in site selection requires consideration of multiple alternative solutions and evaluation criteria. Evaluation procedures involve several objectives, and compromises are often necessary when facing possibly conflicting tangible and intangible factors. These are the reasons why multiple criteria decision-making has been found to be a useful approach for

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solving this kind of problem. There are many methods that could be applied to resolve the complexities involved in site location. Different MCDM (Multi-Criteria Decision-Making) models have been applied to solve this problem. Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and AHP (Analytical Hierarchy Process) techniques are used to solve the problem of site selection.

The importance of choosing an optimal port for callings is highly important for shipping carriers to reduce their total transportation costs.

Decision-makers are required to use linguistic variables to express their preference [11]. The fuzzy multi-criteria analysis provides an effective framework for ranking competing alternatives in terms of their overall performances with respect to criteria [12]. One of the challenging and famous types of MCDM problems that include both quantitative and qualitative criteria is facility location selection problem [13]. Fuzzy set theory combined with MCDM methods provides a suitable language to handle imprecise criteria, being able to integrate the analysis of qualitative and quantitative factors [14].

Many researchers assumed that shippers would aim to minimize their total operation costs by selecting an appropriate port as the most favourable and that inland freight costs could be minimized by shippers selecting the nearest port as the most favourable for their international trade imports and exports. This combined model consists of two stages [15]. For stage one, the container transportation demand split rate is first computed by using the fuzzy multiple criteria decision-making method. For stage two, an optimization mathematical programming network model is proposed for determining the inland origin destination (O-D). The operational performance of merchant ship fleets depends on establishing an effective ship-shore interface, especially on logistic support. This process includes the selection of a marine supplier with respect to a ship's operational requirements, which appears to be a key decision-making issue. Metin [16] offers an integrated decision aid for modelling the marine supplier selection process. The backbone of the proposed methodology consists of a combination of strengths, weaknesses, opportunities and threats, an analytic hierarchy process and a technique for order preference by similarity to an ideal solution. This allows decision-makers to combine market dynamics and the logistic needs of a ship's operating environment, which also includes sea voyages, port periods and docking facilities. A user-friendly interface of the integrated methodology provides shipping executives with opportunities to integrate the proposed methodology into technical ship management procedures.

Chou [17] constructs an Analytic Hierarchy Process model for simulating the behaviour of a carrier when choosing a port and identifying the importance weight of every factor influencing the choice of a port in a multiple-ports region. Finally, the cases of five shipping companies illustrate the utilization of this proposed model.

Fuzzy data represents the uncertain, subjective and imprecise data that must be dealt with very often. Dheena and Mohanraj [18] consider an ideal solution and an anti-ideal solution and assess each alternative in terms of distance as well as similarity to the ideal solution and the anti-ideal solution. Normalization of fuzzy data is carefully avoided to minimize error. OWA operators with maximal entropy are used to aggregate across all criteria and to determine the overall score of each alternative. This proposed method is more flexible in modelling a decision-maker's preferences and more appropriate and effective in handling multiple criteria problems of considerable complexity.

Chou [19] presents a new Fuzzy Multiple Criteria Decision-making Method for solving the selection of a port for a transhipment container under a fuzzy environment.

Chou's [20] study deals with subjective ratings, which are quite commonly used in real life problems. Although a number of research approaches for solving decision-making problems have been proposed, most approaches focus on developing quantitative models for dealing with objective data or qualitative models for dealing with subjective ratings. Few researchers propose approaches to dealing with both objective data and subjective ratings. Use of the proposed fuzzy logic approach is demonstrated with a case study of location choice for a container transhipment port.

Wang et al. [21] proposes an evaluation method to assess logistic distribution centre locations. Logistics service providers find that the selection of a logistic distribution centre is crucial for maximizing their profits and minimizing the costs of their investments. The human preference model usually involves uncertainty in the decision-making process, and it is extremely difficult for decision-makers to express the strengths of their preferences. This paper resolves this problem by establishing a fuzzy multiple criteria decision-making model based on fuzzy AHP for the logistic distribution centre assessment. Thereby decision-makers can express their preference with uncertainty.

The study by De Feo and De Gisi [22] deals with verifying the efficacy of using an innovative criteria weighting tool (the "priority scale") when involving stakeholders. They rank a list of suitable municipal solid waste facility sites with the multi-criteria decision-making technique, known as the analytic hierarchy process.

Tabari et al. [23] states that site selection is part of strategic management activities. This author proposes a hybrid method of multi-criteria decision-making that makes it possible to select the optimal location, which will satisfy the decision-maker. The model is based on the AHP method.

Selection of a proper construction site is of major importance, since this practice is intrinsically collaborative within knowledge-rich and multi-functional working environments [24]. Success at selecting a construction site is what highly determines whether a project is a success or a failure. Different methods for the solution of problems are known. Peldschus et al. [24] proposes applying the theory of two-person, zero-sum games for resolving this problem. Anagnostopoulos et al. [25] proposes the multiple criteria method. TOPSIS and OWA operators are used to aggregate across all criteria with maximal entropy and determine the overall score of each alternative.

Brauers and Zavadskas [26] propose applying the MOORA (Multiple Objectives Optimization by Ratio Analysis) method to resolve location problems.

Önüt [27] presents a model for a shipping centre site selection problem with a real world application in Istanbul, the most populated city in Turkey. A number of conflicting qualitative and quantitative criteria exist for evaluating alternative sites. Qualitative criteria are often accompanied by ambiguities and vagueness. This makes fuzzy logic a more natural approach to these kinds of multi-criteria, decision-making problems. Fuzzy AHP (Analytic Hierarchy Process) is utilized for assigning weights to the criteria for site selection. Meanwhile fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is used to determine the most suitable alternative using these criteria weights. A sensitivity analysis of the results followed in this study.

Zolfani et al. [28] applied AHP and the COPRAS-G method for evaluating the best place for constructing a road. Site selection is very important, because environmental pollution in harbours can have detrimental effects on the port, its users and the surrounding environment. Marin [29] develops a flexible and site-specific, multistep, indicator-based approach, which gives special consideration to local features. Yazdani [2] adopts the fuzzy COPRAS (COPRAS-F) as a fuzzy multi-criteria decision-making technique to determine importance of alternatives with respect to criteria.