Available online at www.sciencedirect.com
ScienceDirect
European Journal of Operational Research 186 (2008) 423–434
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

O.R. Applications

Investment optimization on port's development by fuzzy integer programming

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Received 26 June 2006; accepted 28 January 2007
Available online 20 February 2007

Abstract

In this research, the main purpose is to formulate a model to determine the optimum investment on port development from national investment prospective; on the other hand, costs and benefits are calculated from consumer and investor's viewpoint. The formulated model is an integer-programming model. The emphasis is on how to formulate an investment optimization problem where cargo operation, investment costs, cargo-handling capacity, cargo transportation network, and the world maritime fleet constraints are included. Fuzzy numbers are used for cargo forecast study results. The output of the model is the type of design ships and design berths which are needed in each sub period, so that the port planner (the government) will find out the optimum development plan of port in each sub period when there is uncertainty in cargo handling forecast (fuzzy numbers).

Keywords: Investment; Container terminals; Fuzzy logic; Integer programming model; Port development

1. Introduction

The development of transportation infrastructures has had a great influence on financial and political situation inside countries. In countries like Iran, where more than 90% of cargo transportation (export, import and transit) are done via maritime boundaries, port development is important. Therefore, emphasis should be put on investment in these areas to expand their capacity. Unfortunately, budget limitations restrict the dynamic plans of these countries. There has not been any mathematical method to find the optimum solution for port development. In this paper, the purpose is to formulate an investment model to find the optimum investment steps by application of operational research science and fuzzy logic concept to model the available uncertainties. So fuzzy integer linear programming models are used to determine the optimum investment and

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0377-2217/$ - see front matter
doi:10.1016/j.ejor.2007.01.029

development of a port. In order to formulate this model, Shahid Rajaee port is chosen as a case study port, which has the largest container terminal among southern ports of Iran. The government must develop Shahid Rajaee port to increase its capacity because the container transportation is going to be the most common mode of maritime transportation. On the other hand, seagoing international trade moved by container ships is a major factor in most of the countries. The current cargo handling capacity of the port is about 1,450,000 TEU[2] per year. The cargo forecast results claim that the government should increase its capacity up to about 12,000,000 TEU per year by the year 2030 (Halcrow, 2004). Considering the world maritime fleet development different scenarios should be built and a suitable model will be developed. The most important decision criterion for this project is the budget. Finding an optimum solution, which can lead the investor to develop ports with the lowest costs, has a great importance for developers.

There are different approaches to solve a fuzzy linear program such as Zimmermann approach (Zimmermann, 1996), Chanas approach (Chanas, 1983) and Julien approach (Julien, 1994). According to the results of the cement transportation studies in Taiwan (Shih, 1999), which is a mixed integer programming, the results of these three approaches are close to each other. It is noticeable that Herrera and Verdegay (1995) solved three types of fuzzy integer linear programming using fuzzy constraints, imprecise costs, and fuzzy coefficients. The other solution for solving integer programming is the Chanas solution for integer transportation problem (Chanas and Kuchta, 1998). In this study because of the large scale of this problem the Julien's approach is used to yield the optimum result. If the problem was continuous optimization it would be possible to solve the problem by using Shian-Tai method too (2004). The problem in this study is a complicated and developed form of fixed-charge problem (Hillier and Lieberman, 2001) with fuzzy numbers on the right hand side of some constraints.

2. Preliminaries

In this section a brief definition of fuzzy numbers, α-cut and Julien's approach are given.

2.1. Fuzzy numbers

A fuzzy number $\widetilde{M}$ is a convex normalized fuzzy set $\widetilde{M}$ of the real line R such that:

I. It exists exactly one $x_0 \in R$ with $\mu_{\widetilde{M}}(x_0) = 1$.
II. $\mu_{\widetilde{M}}(x)$ is piecewise continuous (Zimmermann, 1996).

In this research, all fuzzy numbers are shown with $\sim$ symbol.

2.2. α-cut

The crisp set of elements that belong to the fuzzy set $\widetilde{A}$ at least to the degree α is called the α-cut, (Zimmermann, 1996):

$$A_\alpha = \{x \in X | \mu_{\widetilde{A}}(x) \geqslant \alpha\}.$$

2.3. Julien's approach for solving fuzzy LP models

In this research, Julien's approach will be used to solve the integer linear problem of the model. So the approach is briefly described. Julien (1994) proposed an approach that incorporates the α-cut concept with Buckley's (1989) possibility programming to resolve the problem including fuzzy objective and fuzzy RHS[3]

[2] Twenty Equivalent Unit.
[3] Right Hand Side.