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Using Pareto-based multi-objective Evolution algorithms in decision structure to transfer the hazardous materials to safety storage centre

Farzad Mahmoudsoltani [a], Hamid Shahbandarzadeh [b, *], Reza Moghdani [b]

[a] Department of Industrial Engineering, Payame Noor University, Ramsar, Iran
[b] Departement of Industrial Management, Persian Gulf University, Boushehr, Iran

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ABSTRACT

The influence of Hazardous Materials on different kind of human aspects motivate scholars to increase their attention for decreasing negative impacts of them to human life. In this concern, this paper addresses a decision structure to transfer the hazardous materials to the safe location in the industries logistic system. To reach this goal, we present a new mathematical modelling problem in which location routing problem of hazardous material is addressed. To cope imprecise risk in a practical way, we define it to three kinds in the fuzzy environment including accident risk, population risk, and the bio-environmental risk. To obtain optimal results, three well-known multi-objective evolutionary algorithms (MOEAs) including Non-dominated Sorting Genetic Algorithm II (NSGA-II), Strength Pareto Evolutionary Algorithm II (SPEA-II) and Multi-Objective Evolutionary Algorithm Based on Decomposition (MOEA/D) are presented for solving ten test problems. In this case, this novelty of the model is discussed, firstly, and then proposed algorithms are compared with respect to obtained results. The results of this paper show that Non-dominated Sorting Genetic Algorithm II (NSGA-II) has superior performance in terms of metrics, and Strength Pareto Evolutionary Algorithm II (SPEA-II) beats other multi-objective evolutionary algorithms in terms of obtained number of individuals in final Pareto solutions.

1. Introduction

According to the official reports seen in the literature (Xie et al., 2012a), transportation of Hazardous Materials (HAZMAT) from 2002 to 2007 grew rapidly. HAZMAT transportation is one of a significant issue receiving substantial attention among scholars. Millions of tons of commodity are transferred daily throughout the world which consists of the hazardous cargoes. The HAZMAT is attributed to a material which is capable of causing the living, financial and bioenvironmental losses. In such case, a truck carrying chlorine gets involved in an accident, it will be followed by harrowing results for people of a region and even, forces them to abandon their houses (Erkut and Gzara, 2008).

Another unpleasant event, in this case, can be HAZMAT leakage as a result of a driving accident. This feature of the HAZMAT forces the decision makers to consider the risk reduction as an important criterion in their own calculations. According to (Paredes-Belmar et al., 2017), the unforeseen factors affects the possibility of an accident leads to the unpleasant consequence of HAZMAT transportation, and the revulsion results of this kind of accident have a dramatic impact on human life. This point causes people to be extremely sensitive to HAZMAT transport and its special shipment in comparison with another type of goods (Bianco et al., 2013). Allowable routes for transferring HAZMAT are determined with regard to several criteria including the safety of route, bio-environmental conditions and the population surrounding the used roads; so that, the shortest route is not specified necessarily. Therefore, planning principal difference for HAZMAT transmission is related to take the risk factor into consideration.

Therefore, the risk which is extensively studied in this case is defined as probability and intensity of loss and damage to exposed society as a result of an unpleasant event in the HAZMAT (Alp, 1995). There are two main types of risk evaluation including: qualitative and quantitative. Qualitative evaluation of risk is estimated through identification of probable events scenarios and making an effort for approximating estimation of the undesirable results, and often used when there is no reliable quantitative information in order to estimate possibility and intensity of the event accurately, and in another hand, quantitative evaluation is

* Corresponding author.
E-mail address: shahbandarzadeh@pgu.ac.ir (H. Shahbandarzadeh).

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performed when required information in order to develop the risk estimation models are provided (Seyedhosseini and Mahmoudabadi, 2010).

The growth in the number of studies related to HAZMAT transportation shows the importance of this issue among researchers. In another hand, the lack of comprehensive study on multimodal HAZMAT location and routing compel additional research in this area. Generally speaking, multi-model HAZMAT location and routing is fundamentally differenced from the single mode in which transportation of HAZMAT is carried out throughout different modes that encompasses more realistic situation than single mode. For more clarification, Fig. 1 one indicates the simple network of multimodal including origin-destination and highway that is extensively noticed in literature. As shown in Fig. 1, highways and pipelines depicted for utilizing our proposed model, and transfer yard nodes are used to connect pipeline and highway in the multimodel network in which transferring of HAZMAT from truck to pipeline station and vice-versa. In this figure, red and yellow squares indicate transfer yard and origin-destination in HAZMAT multi-model network, respectively.

Another important aspect of HAZMAT transportation is the determination of facility location for HAMAT. The single facility location problems are one of the expansive domains in the mathematical modelling in the real world. Many researchers, like (Zografos and Androutsopoulos, 2008), believes that combination of undesirable facility location and routing considered in the decision-making process can be efficient. In this research, in order to prevent from the perils originated from HAZMAT in the various industries, we develop a decision structure to transfer the HAZMAT to the safe location in the industries logistic system.

In this study, we are going to determine to optimize HAZMAT location and routing that include numerous modes, and considered risk depends on the products transported by the vehicle on any route. We also assume that associated risks to the links are uncertain that follow fuzzy rules. While we will use evolutionary approach is this study, the Taguchi method is applied to design optimum parameters of each algorithm for various test problem size.

We also implement Priority-based encoding (PBE) method, one of the well-known procedures to cope with routing problems, to describe solution representation of any solution which is performed in evolutionary algorithms. While there is no test function in this special case, different types of test functions are randomly generated to show the validity of a proposed formulated integer programming model that is solved using the well-known multi-objective evolutionary algorithm. To the determine an approximate set of non-dominated solutions, we use including NSGA-II, SPEA-II, and MOEA/D. Finally, a real HAZMAT case in a transportation network in the Khuzestan Province, Iran, is solved.

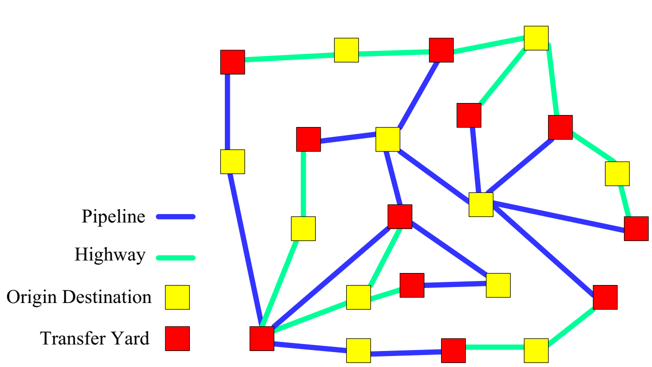

Fig. 1. A typical network for multi-modal transportation.

The rest of the paper is organized as follows. Reviews on the literature of previous studies are conducted, including undesirable facilities location, routing of HAZMAT transportation. 2. The calculation of risk is regarded in section 3. The problem definition and our proposed structure model are described in section 4. Multi-objective evolutionary algorithms (MOEAs) are defined in section 5. After a brief explanation about solution methods in section 5, Taguchi method is used to determine the best value of each factor of proposed algorithms in section 6, and then the results of the experiment are analyzed. Finally, in the seventh section, conclusion, and suggestions for future researchers are provided.

2. Literature review and previous studies

The studies conducted HAZMAT transmission have been classified into the following group including risk (Shome et al., 2018), developing decision support systems (DSS) (Zografos and Androutsopoulos, 2008), routing, the combination of location problem with routing problem (Samanlioglu, 2013)and, finally, network design (Bianco et al., 2009). Erkut et al. (Erkut et al., 2007).

Even if it seems that comprehensive study is required to undertake significant recent studies, it is out of the goal of this research, and we just focus on location, routing, and the combination of location and routing problem that more related to our problem.

There are many studies have considered the HAZMAT routing problems. Akgün et al. (2007), addressed the effects of weather systems on hazmat routing by using different types of heuristics. Bonvicini and Spadoni (2008) studied routing HAZMAT by integrated into the TRAT4-GIS software. They showed the efficient procedure which is helping managers in the decision-making process. Sherali et al. (1997), developed and analyzed a mathematical model for finding a route reducing the risk of low probability-high consequence by using a branch-and-bound approach. Kazantzi et al. (Kazantzi et al., 2011, Iakovou et al., 1999) implemented randomize procedure based on Monte Carlo simulation for risk assessment. Iakovou et al. (Iakovou et al., 1999) developed a two-phase solution approach for maritime HAZMAT routing problem. In the specific study, Verma (2009) considered railway network by introducing the bi-objective model to minimize the risk of transporting HAZMAT. Another study was directed by Verma et al. (2011) that is considered transporting HAZMAT and using developed a genetic algorithm.

On top of vehicle routing, many studies have also been conducted on facility a location for treating HAZMAT Studies regarding optimal location from viewpoint of geographers and scholars of economic science take into consideration recently. Models of these studies which consider the facility common points to be undesirable and, prefer that they are far away from their own location (Cappanera, 1999). Current and Ratick (1995) utilized an off-the-shelf optimization tool to solve a multi-objective HAZMAT location problem. Cappanera et al. (2003) proposed location and routing model for obnoxious activities which was solved by using Lagrangean relaxation and a Branch and Bound algorithm. Helander and Melachrinoudis (1997) conducted a path reliability model to determine the optimum facility location. Berglund and Kwo (Berglund and Kwon, 2014) proposed a robust facility location problem for hazardous materials (hazmat) in which minimize total cost, in terms of fixed facility cost, transportation cost, and exposure risk are considered. List and Mirchandani (1991)developed a multi-objective framework which is useful for HAZMAT location decisions by considering various types of risk.

The last aspects of the HAZMAT management, the most significant, is integrating location and routing problems which mostly formulated as multi-objective optimizations. The pioneering