Transportation Research Part E 80 (2015) 74–94

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

A multi-objective healthcare inventory routing problem; a fuzzy possibilistic approach

Farzad Niakan *, Mohammad Rahimi

INSA-Lyon, DISP Laboratory EA4570, Villeurbanne, France

ARTICLE INFO

Article history:
Received 28 November 2014
Received in revised form 21 April 2015
Accepted 22 April 2015
Available online 11 June 2015

Keywords:
Inventory routing problem
Healthcare
Fuzzy mathematical programming
Possibilistic programming
Fuzzy multi-objective optimization

ABSTRACT

This paper presents a new multi-objective mathematical model to address a Healthcare Inventory Routing Problem (HIRP) for medicinal drug distribution to healthcare facilities. The first part of objective function minimizes total inventory and transportation costs, while satisfaction is maximized by minimizing forecast error which caused by product shortage and the amount of expired drugs; Greenhouse Gas (GHG) emissions are also minimized. A demand forecast approach has been integrated into the mathematical model to decrease drug shortage risk. A hybridized possibilistic method is applied to cope with uncertainty and an interactive fuzzy approach is considered to solve an auxiliary crisp multi-objective model and find optimized solutions.

1. Introduction

In the last decades, the increasing number of published studies in the context of healthcare shows that healthcare issues are of considerable interest to both academia and practitioners (Rais and Viana, 2011; Kumar and Rahman, 2014). The healthcare world is faced with various challenges coming from different sides, such as manufacturing and supplying. In recent years (2007–2011) in the U.S., the frequency of drug shortages increased by about 40% while 13% of shortage causes were related to distribution and inventory policies as reported by U.S. department of health and human services (2012) (Fig. 1). In order to tackle distribution and inventory problems in healthcare, various related Operation Research (OR) problems can be applied. Among them, the Inventory Routing Problem (IRP) may lead to efficient tools that monitor and address both inventory and distribution issues. The integration of IRP (HIRP) models in healthcare leads to a decrease in the frequency of drug shortages in healthcare facilities by defining a set of facilities to which the drugs are to be delivered, a sequence of transportation routes, and the quantity of drugs to be delivered to each facility.

Global warming and the rise of environmental pollutants, particularly via GHG emissions, present a worldwide challenge. Transportation activity is one of the main sources of GHG emissions, while reducing GHG emissions is the main objective of the IRP. Via applications of the HIRP, priority is given to the GHG issue, which has wide effect on public health, by decreasing the amount of GHG released by vehicles during drug distribution.

With regard to the matters enumerated, the aim of this research is to present a new multi objective mathematical model for integrating the healthcare issues and inventory routing problem under uncertainty. The objective functions that are considered in the model, minimize the total cost, forecast error which caused by product shortage, amount of expired and GHG

* Corresponding author. Tel.: +33 685765729.
E-mail address: farzad.niakan@insa-lyon.fr (F. Niakan).

http://dx.doi.org/10.1016/j.tre.2015.04.010
1366-5545/

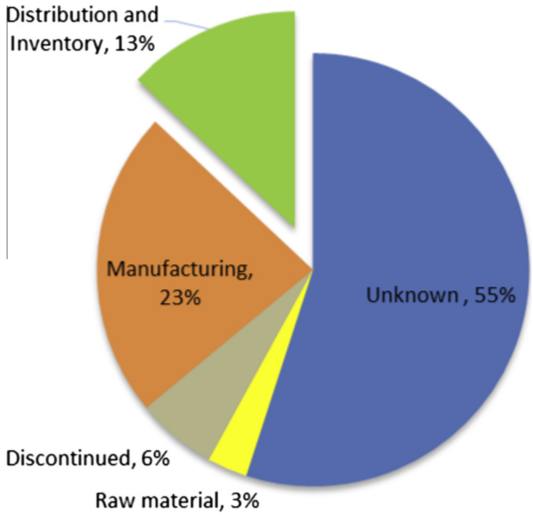

Fig. 1. Causes of drug shortage in U.S. (2011).

emission. Furthermore, a demand forecast approach is applied to decrease shortage risk. Then, an interactive fuzzy approach is considered due to lack of the information about some parameters.

The remainder of this paper is organized as follows: Section 2, reviews the related literature about IRP and presents research motivations and contributions; notation and the mathematical model are presented in Section 3; Section 4, is related to applied linearization methods; Section 5, elaborates on the solution and approach for the proposed mathematical model; Section 6, includes experimental results and analysis; concluding thoughts and future research options comprise Section 7.

2. Literature review

IRP was first introduced by Bell et al. (1983) by integrating decisions on inventory, vehicle scheduling, and gas distribution methods for the delivery of chemical products. Several researchers extended this study, such as Anily and Federgruen (1990), Dror and Ball (1987), Speranza and Ukovich (1996). Several concepts are studied by researchers in inventory routing problem; some authors consider cost or profit as objective functions (Archetti et al., 2007; Moin et al., 2011). Other studies focus on the minimization of traveling time (Li et al., 2014), a topic closely related to the distribution of perishable products or disaster situations and some others (Jozefowiez et al., 2008; Yu et al., 2010) consider other criteria such as service level and customer satisfaction in routing problems.

Due to the large number of studies related to the inventory routing problems, we limit ourselves to the mention some important studies here. Federgruen and Zipkin (1984) extended some methods for vehicle routing problem and combined the location and allocation delivery planning in their study. Golden et al. (1984) addressed the combined problem of vehicle routing and inventory problems and they used simulation model for investigation this combination. Berman and Larson (2001) investigated on IRP in gas industry. They minimized some related cost such as expected cost, costs of earliness, lateness, product shortfall, and cost of returning. The authors used stochastic dynamic programming to model the problem. Jaillet et al. (2002) investigated IRP for distribution some products such as heated oil from depot to large number of the customers. They considered cost approximation to minimize the total delivery costs. Kleywegt et al. (2002) applied Markov decision process to formulate the IRP and also an approximation method is considered to solve the model. Moin and Salhi (2006) classified the literature review of the IRPs. Also Andersson et al. (2010) categorized the IRPs according to the finite or infinite planning horizons, deterministic or stochastic demands, limited or unlimited number of vehicles and one or multiple customers visited. Moreover recently, Coelho et al. (2013) did a comprehensive survey on inventory routing problems. Custódio and Oliveira (2006) proposed a new model for the distribution of frozen foods by considering the interaction between retailer and supplier. Hsu et al. (2007) studied a stochastic vehicle routing problem with time windows for delivering perishable food from the distribution center. They considered cost minimization based on different costs, such as inventory, transportation, energy, and a penalty for violating time windows. Archetti et al. (2007) addressed mixed-integer linear programming in IRP while considering a maximum inventory level and a replenishment policy. The authors proposed a branch and cut algorithm to find optimal solutions. Savelsbergh and Song (2008) studied continuous moves in the IRPs for a closer approximation of real-life conditions. They also proposed a local search-embedded heuristic to find better solutions. Li et al. (2008) integrated replenishment procedure in IRPs without shortage consideration. Chen and Lin (2009) addressed multi-product and period IRP optimization models by considering stochastic demand and risk aversion. Abdelmaguid et al. (2009) considered multi-period IRP with backlogging. The authors subsequently proposed a new heuristic to solve