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Blood supply chain network design under uncertainties in supply and demand considering social aspects

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A R T I C L E I N F O

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A B S T R A C T

Blood supply chain design is an issue which has been investigated in the literature to some extent. Blood donation is a voluntary activity and blood donors are important in the blood supply chain. It is suitable to attempt to increase blood donors' utility in order to reduce shortages and harmful damages. Parameters including distance of blood donors from blood facilities, experience factor of donors in blood facilities and advertising budget in blood facilities are considered social aspects and applied to form utility function used in this paper. The aim was to increase utility and motivate blood donors to donate blood. First, a deterministic location-allocation model is proposed applying a mixed integer linear programming (MILP) optimization. Due to the stochastic nature of demand and cost parameters, the aforementioned model is developed to incorporate uncertainty using a robust optimization approach that can overcome the limitations of scenario-based solution methods, i.e., without excessive changes in complexity of the underlying base deterministic model. The application of the proposed model is evaluated by a case study in Tehran. Numerical results obtained and sensitivity analysis helps administrators in the decision making process for investment projects.

1. Introduction and literature review

Human blood is a scarce resource that only can be produced by human beings and currently there is no substitution for it and its products (Cohen and Pierskalla, 1975). To provide adequate levels of blood products in a safe manner for both electives as well as emergency procedures is a great challenge in healthcare environments. The need for blood donors and blood products always exist and supply of blood donors is irregular and demand for blood products is stochastic (Belien and Force, 2012). Demand and supply match in an efficient way for this product is not simple. Perishability of blood and blood products makes the problem harder. Blood shortage increases fatalities rate and causes high costs for society (Belien and Force, 2012). Therefore, proper blood network design is of great importance. In a blood supply chain, blood donors voluntarily visit blood facilities to donate blood. Blood units are transferred to relevant locations for required tests and then the distribution is done according to demand of hospitals.

Different approaches are used to model a blood supply chain. Simulation, dynamic programming, integer programming and goal programming are among common approaches.

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1.1. Simulation

Haijema et al. (2007) proposed a model by using Markov dynamic programming and simulation approach for Netherlands blood bank. Their study focused on production cost and inventory management of platelets. Kopach et al. (2008a) used a model to investigate different levels of demand, service, costs and shortages. This paper applied queue models to determine optimized policies. Results obtained by simulation models are confirmed by real data in Canada. Alfonso et al. (2012) investigated processes of collecting blood in relation to establishing cost of temporary and permanent blood facilities in France. They used Petri nets to describe different processes of collecting blood, donors' behavior and human resources. Baesler et al. (2014) created a discrete event simulation model to analyze proposed inventory policies in a regional blood center. Different scenarios were considered. Each scenario represents different inventory policies consisting of a combination of an optimal inventory, a reorder point, and a level of extra donations. Zahraee et al. (2015) applied dynamic simulation and Taguchi method to design a robust blood supply chain system to improve its efficiency. They chose four factors including arrival rate of donors, minimum and maximum inventory levels and blood delivery policy. Results showed all main factors should be put at the high level except for factor B. Similarly (Jagannathan and Sen, 1991; Kopach et al., 2008b; Kamp et al., 2010; Duan and Liao, 2013, 2014; Asllani et al., 2014; Katsaliaki et al. 2014) used a simulation approach.

1.2. Dynamic programming

Zhou et al. (2011) investigated inventory management of blood platelets considering life time of platelets which is limited to three days. They used a dynamic programming to solve the studied problem.

1.3. Integer programming

Sapountzis (1984) used an integer programming model to investigate demand of blood and blood products and optimized allocation of blood products to hospitals. The objective function aimed to minimize blood units returned to the blood centers. Jacobs et al. (1996) used integer programming models for locating blood facilities in Norfolk. Their findings presented collecting activities and distribution of blood products. Hemmelmayr et al. (2009) used integer programming in the problem of delivering blood products to Austrian Hospitals with the aim of minimizing cost of both delivery and spoilage. They compared the current vendor-managed inventory setup with vendor-managed inventory system. Ghandforoush and Sen (2010) minimized production cost of platelet for a regional blood center by an integer nonlinear programming model. They transferred the objective function and quadratic constraints to linear form and integer programming in order to solve the problem.

1.4. Goal programming

Kendall and Lee (1980) developed a goal programming model to investigate different objectives of inventory levels, availability of blood, decrease in outdated blood and collecting cost. Data of a blood center in Midwest is used to achieve results. Nagurney et al. (2012) proposed a model including collecting facilities, laboratory facilities, storage facilities and distribution centers. They developed a general network using multi-criteria optimization approach to investigate overall operational cost in chain and risks of inventory and shortage.

1.5. Considering uncertainty in parameters

Hemmelmayr et al. (2010) extended the approach of Hemmelmayr et al. (2009) to investigate vendor managed inventory resupply policies in the presence of stochastic product usage. Gunpinar and Centeno (2015) proposed a stochastic integer programming model considering two levels of one hospital and one blood center. Their aim was to decrease total cost, shortage level and inventory level over planning period. Zahiri et al. (2015) used a mixed integer linear programming model to investigate location and allocation decisions over multi-period planning horizon and considered fuzzy parameters. Jabbarzadeh et al. (2014) proposed a robust network to provide blood in critical conditions for multiple post-disaster periods. Fahiminia et al. (2017) presented a stochastic bi-objective supply chain design model for the efficient and effective supply of blood in disasters. This paper focused on exploring possible tradeoffs between supply chain cost and delivery time and determining sections to improve efficiency and effectiveness. Hosseinifard and Abbasi (2016) studied the importance of inventory centralization at the second echelon (hospitals) of a two echelon supply chain. The results demonstrated that the centralization of hospitals' inventory is important in the blood supply chain and can increase the sustainability and resilience of the proposed chain. Kohneh et al. (2016) proposed a bi-objective mixed integer programming model considering unstable conditions during the disaster by using fuzzy parameters. Application of the proposed model is effective in generating solutions under earthquake conditions. Osorio et al. (2016) investigated an integrated simulation optimization decision in production planning. Discrete event simulation is used to represent flows. An integer linear optimization model running over a rolling planning horizon is used to support decisions. Zhuge et al. (2016) demonstrated a traditional problem locating distribution centers under uncertain demand and proposed a stochastic programming model on locating distribution centers,