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Modelling the Supply Chain to Destruct Expired Medicines at the Time of Occurring Natural Disasters

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ABSTRACT

The supply chain of relief items plays a key role in decreasing damages at the time of occurring crises and natural disasters. It is highly significant to pay attention to the expiration dates of medicines and it is possible to perform proper planning in order to help the injured people considering the time left until the expiration date. In this study, we study the supply chain modeling by considering the decisions related to activating the required facilities and the amount of medicines stocked in them before the crisis, and the decisions related to distributing medicines after the crisis. The under-consideration supply chain provides the required medicines and destroyers expired ones at the time of a crisis. It is required to consider suitable locations for medicine storehouses before occurring a crisis so that it is possible to distribute medicines to hospitals with proper efficiency in terms of considered objectives. These medicines should be stored in suitable quantities in warehouses and expired medicines are required to be transferred at a suitable time in order to minimize the shortage of medicines in the event of a crisis, and also to send medicines to hospitals in the affected regions at the accurate time.

1. Introduction

In general, disaster is referred to an event which appears naturally or human-made, suddenly or increasingly, which is saddled by difficulty and travailed to the society, thus, dispeling it, needs fundamental actions. Natural disasters like flood, earthquake and storm involve many parts of the world every year (Habibi-Kouchaksaraei et al., 2018). Natural disasters can cause many harms such as life losses, decreases in livelihood conditions, severe damages to infrastructure and buildings and unemployment. Data from the Centre for Research on the Epidemiology of Disasters (CRED) shows an increasing occurrence of natural disasters all over the world in the last decade and their impact on society expressed in number of victims, people affected and increase in economic costs. Data on the global distribution of natural hazards indicate that although droughts have a much lower occurrence than floods and storms together, they impact a larger number of victims. Some characteristics, such as poor infrastructure and lack of planning and governmental preparedness, worsen the impact of natural disasters in emerging and developing economies than in more developed ones. Disasters can more severely affect economic activities and growth in developing economies, as a wide range of industry sectors may be affected (Silva et al., 2018).

Healthcare systems constantly provide new challenges to their managers and decision-makers due to high demands for service, high costs, limited budget, and healthcare resources (Feili, 2013). During a disaster occurs, usually the amount of demand for medical and health care needs will increase. In the disaster mitigation efforts, rapid response meeting the medical needs of disaster victims are emphasized to the rescue and recovery situation. Meeting the needs of medical and health services into the health care supply chain are very important. The success of disaster mitigation operations is influenced by how the healthcare system can run in disaster supply chain process. The efficiency and effectiveness of operational processes in the healthcare supply chain are expected to reduce the impact of greater losses, especially victims. Since it is very urgent issue of disaster, lately many researchers are paying attention to the study of supply chain management for disaster (Syahrir & Suparno, 2015).

The concept of supply chain management (SCM), since their appearance in 1982, is associated with a variety of meanings. In accordance with the Global Supply Chain Forum, the SCM is the integration of key business processes, from final users to original suppliers providing products, services and information which add value to clients, shareholders, etc. (Feili & Hassanzadeh Khoshdooni, 2011). SCM integrates interrelationships between various entities through creating alliance, such as, information-system integration and process integration, between entities to improve response to customers in various aspects such as, higher product variety and quality, lower costs and faster responses (Feili et al., 2012). SCM is seeking approaches to support suppliers, vendors and consumers in such a way that services, production and distribution are always on time and in appropriate locations to satisfy the customers' demands (Samani et al., 2018). Research that explores ways to mitigate supply chain disruptions has generally followed one of two streams: disruptions caused by anticipated and unanticipated disasters. In practice, a supply chain frequently faces disruptions with anticipated probability of occurrence and magnitude of impact, due to forecast errors caused by demand fluctuations, machine breakdown, and poor supplier performance (Chen et al., 2015). The supply chain problems that arise during the pre-disaster and post-disaster stages resemble the well-known facility location problem combined with assignment/transportation considerations (Noham & Tzur, 2018).

Natural disasters usually damage human life and property. Factors such as population growth, climatic changes, and the integration of natural disaster systems are increasing, hence, it is predicted that current relief to be inadequate and ineffectual. Planning in order to encounter such consequences and public awareness has reduced deaths and property losses and injuries, which is a key approach in relief responses. Such an emergency and complex situation required a decision-maker to respond quickly and effectively to logistical problems, and the efficiency and agility of operations depend not only on supplies at the time of the occurring crisis but are also affected by the arrangements and actions envisioned in order to satisfy the requirements at the time of occurring the crisis.

Logistics coordinates more the delivery of goods and communications and increases the speed of delivery and responsiveness. Medicines required at the time of an accident are among the needed relief items that play a significant role in relieving the injured population. It is not possible to obtain medicines quickly in the event of a crisis in some cases, accordingly, it is extremely common to store medicines in logistics warehouses to provide them to applicants quickly in the event of an accident. Managing the inventory of these medicines has higher complexity and uncertainty compared to other commodities due to the uncertainty of the time of occurring the crisis. Medicines are also important in normal conditions, but the medicines and relief items have multiple significance in times of occurring the crisis. The inventory control model and the integration of pre-crisis and crisis decisions have been studied in this study.

1. Finding

1.1 The structure of the studied network

An inventory control system is considered for pharmaceutical items in which medicines are stored for several periods in order to be used in the event of an emergency. It is possible that an accident occurs in different scenarios from the moment the medicines are stored in the warehouse in any future period, accordingly, the goods that have been stored in the warehouse are required to be able to respond in the event of a crisis.

The studied supply chain obtains the medicines required in the event of a crisis. Consequently, it is required to consider proper locations for medicine storehouses before occurring the crisis in order to distribute medicines to hospitals with appropriate efficiency in terms of the planned objectives. It is required that these drugs to be stored in appropriate quantities in warehouses and expired medicines must be taken out at the appropriate to minimize the shortage of medicines in the event of a crisis, and also to distribute medicines to hospitals in the affected regions at the right time and observing the justice. The studied logistics network includes: hospital, central warehouse, local warehouse, manufacturer.

Two types of medicines have been considered in this research. Two types of medicines with multiple storage conditions are purchased from the manufacturer. Type A medicines have no special storage conditions (such as cold pills). Type B medicines have special storage conditions (like IVIG). We store Type B medicines in a central warehouse. Type A medicine is brought from the central warehouse to the local warehouse. The manufacturer sends both types of medicine to the central warehouse. Medicines with a closer expiration date are sold in the market. Expired medicines are removed from a warehouse and destroyed. Medicines with an expiration date are transported from the local warehouse to the hospital.

1.2 Research hypotheses

The assumptions considered in the research model are as follows:

A. There are various potential locations to establish distribution centers, but it is required that the accurate number of distribution centers be determined by the model.

B. The solution space is discrete; this means that distribution centers are required to be located among several potential points that are safer than other locations at the time of occurring crisis.

C. Hospital demand is expected at the time of the event.

D. The total amount of requests designated to each central warehouse in all its routes should not be more than the capacity of the warehouse.

E. Warehouses have different capacities. In fact, warehouses are classified into three categories: small, medium, and large. The model is responsible for selecting the type of warehouse and the decision is made according to the amount of demand.

F. The introduced model is multi-commodity and there is a specific volume, different manufacturing costs, shortages, and maintenance for each relief item.

G. Not only, no benefit will be considered to destroy expired medicines if reprocessing/reproducing is not possible, but the cost of destruction should be also considered.

1.3 Indices, variables, and parameters

We introduce variables and parameters in two categories: scenario independent and scenario dependent. We explain the gene ral notation applied in the research model as follows:

1.3.1 Indices and sets applied in the model

Collections/set	Description
J	A set of potential locations to construct the local warehouse $j \in \{0,1,...,\|J\|\}$
K	Hospital Set $k \in \{1,...,\|K\|\}$
U	A set of all network nodes $U = J \cup K; u, u' \in \{1,...,\|U\|\}$
B	A set of Type B medicines $\beta \in \{1,...,\|\mathrm{B}\|\}$
A	A set of Type A medicines $\alpha \in \{1,...,\|A\|\}$
C	A set of all medicines $C = A \cup B; c \in \{1,...,\|C\|\}$
T	A set of pre-crisis time periods $t \in \{1,...,\|\mathrm{T}\|\}$
E_c	A set of remaining periods of medication remaining service life Type c $e_c \in \{1,2,...,\|E_c\|\}$
T’	A set of post-crisis time periods $t' \in \{1,...,\|T'\|\}$
V	A set of all vehicles $v \in \{1,...,\|V\|\}$
Ψ	A set of all possible scenarios $\Omega \in \{1,...,\|\Psi\|\}$

1.3.2 Model parameters

The model parameters are classified into two categories, scenario-dependent, and scenario-independent. Scenario-independent parameters are as follows:

A. Scenario-independent parameters

Description	Parameter
FJ_j	Fixed cost of constructing a local warehouse on location j
$ds_{uu'}$	The distance between node u to u' in the network
e_c	Maximum production of type c medicine per period in the manufacturer
$R1_j$	The distance of the local warehouse that is constructed at location j as the local warehouse of the hospitals
a_{jk}	Parameter with a value of 1 if the hospital k is located inside the radius of coverage of the local warehouse j as a local warehouse and with a value of zero otherwise

$CC1_{cj}$	The cost of developing capacity level 1 for product c in warehouse j
$CC2_{cj}$	The cost of developing capacity level 2 for product c in the warehouse j
$CC3_{cj}$	The cost of developing capacity level 3 for product c in the warehouse j
DS_c	The cost of destroying Type c medicine if it is expired
$H1_c$	The cost of keeping each unit of Type c medicine in the warehouse
CP_c	The cost of medicine Type c production before occurring the crisis
$Cap1_{cj}$	Level 1 capacity of warehouse j for Type c medicine
$Cap2_{cj}$	Level 2 capacity of warehouse j for Type c medicine
$Cap3_{cj}$	Level 3 capacity of warehouse j for Type c medicine
FV_v	Fixed cost of applying a type v vehicle
MV_v	Variable cost of vehicle v
Q_v	The capacity of vehicle v
M	A large enough number

B. Scenario-dependent parameters

Parameter	Description
P_Ω	Possibility of occurring the scenario Ω
$D_{ckt'\Omega}$	The amount of hospital demand k from medicine type c in period t 'in the scenario Ω
$ac_{cj\Omega}$	Percentage of medicine type c that has been stored healthy in the local warehouse j in the scenario Ω

1.3.3 Model variables

A. Scenario-independent variables

Variable	Description
y_j	Binary variable with value 1 if the warehouse j to be activated before the crisis.
$z1_{cj}$	It will be 1 if the capacity level of 1 medicine type c for the warehouse j is considered in case of construction and otherwise will be zero.
$z2_{cj}$	It will be 1 if the capacity level of 2 medicine type c for the warehouse j is considered in case of construction and otherwise will be zero.
$z3_{cj}$	It will be 1 if the capacity level of 3 medicine type c for the warehouse j is considered in case of construction and otherwise will be zero.
U_{kj}	Binary variable with value 1 if hospital k is allocated to warehouse j as a local warehouse.
$I1_{cje_ct}$	Inventory level of medicine type c with remaining life in warehouse j in period t.

G_{cjt}	The amount of medicine type c with the remaining life E_c (maximum life) that is produced in period t for the warehouse j.
N_{jv}	A number of v-type vehicles designated to the warehouse j.

B. Scenario-dependent variables

Variable	**Description**
$L1_{ovtt'\Omega}$	A number of v-type vehicles employed in the central warehouse at time t 'when the crisis happens at time t.
$L2_{jvtt'\Omega}$	A number of v-type vehicles employed in the central warehouse j at time t 'when the crisis happens at time t.
$x1_{cjvtt'\Omega}$	The amount of medicine type c delivered by vehicle v from the central warehouse to the local warehouse j in the scenario Ω at time t 'when the crisis happened during period t.
$x2_{cjj'vtt'\Omega}$	The amount of medicine type c delivered by vehicle v from the central warehouse j to the local warehouse j' in the scenario Ω at time t 'when the crisis happened during period t.

1.4 Modeling of expired medicines in critical situations

$$\min \Pi^f = \sum_{j\in\{1..|J|\}} (FJ1_j.y_j + FJ2_j.y_j + FJ3_j.y_j) + \sum_{j\in J}\sum_{c\in C}(CC1_{cj}.z1_{cj} + CC2_{cj}.z2_{cj} + CC2_{cj}.z2_{cj}) - \\ + \sum_{c\in C}\sum_{j\in J}\sum_{t\in T} CP_c.G_{cjt} + \sum_{v\in V}\sum_{j\in J} FV_v.N_{jv} + \sum_{j\in J}\sum_{v\in V}\sum_{t\in T} MV_{v,t}.N_{jv} + \sum_{c\in C}\sum_{j\in J}\sum_{e_c\in E_c}\sum_{t\in T} H1_c.I1_{cje_ct} + \sum_{c\in C}\sum_{j\in J}\sum_{t\in T} DS_c.I1_{cj0} \tag{1}$$

s.t.

$$\sum_{j\in J\backslash 0} a_{jk}.U_{kj} = 1 \qquad \forall k\in K \tag{2}$$

$$\sum_{k\in K} U_{kj} \le M.y_j \qquad \forall j\in J\backslash 0 \tag{3}$$

$$I1_{\alpha j e_\alpha t} = 0 \qquad \forall \alpha\in A,\ j\in\{1,...,|J|\}, e_\alpha\in E_\alpha,\ t\in T \tag{4}$$

$$G_{\alpha jt} = 0 \qquad \forall \alpha\in A, j=\{1,...,|J|\}, t\in T \tag{5}$$

$$I1_{cj(e_c-1)(t+1)} = I1_{cje_ct} \qquad \forall j\in J,\ c\in A, t\in\{1,...,|T|-1\}, e_c=\{2,...,|E_c|\} \tag{6}$$

$$I1_{cj(|E_c|)t} = \sum_{t\in T} G_{cjt} \qquad \forall c\in C, j\in J, t\in\{1,...,T\} \tag{7}$$

$$\sum_{j\in J} G_{cj1} \le e_c \qquad \forall c\in C \tag{8}$$

$$G_{cj1} \le Cap1_{cj}.z1_{cj} + Cap2_{cj}.z2_{cj} + Cap3_{cj}.z3_{cj} \qquad \forall c\in C, j\in J \tag{9}$$

$$z1_{cj} + z2_{cj} + z3_{cj} = y_j \qquad \forall c\in C,\ j\in J \tag{10}$$

$$\sum_c\sum_v\sum_t\sum_{t'} x2_{ckjvtt'\Omega} \le M.U_{k,j} \qquad \forall j\in J, k\in K, \Omega\in\Psi \tag{11}$$

$$L1_{vtt'\Omega} \ge \frac{\sum_{j'\in J\backslash 0}\sum_{c\in C} x1_{cj'vtt'\Omega}}{Q_v} \qquad \forall v\in V, t\in T, t'\in T', \Omega\in\Psi \tag{12}$$

$$L2_{jvtt'\Omega} \geq \frac{\sum_{j' \in \{J \cup K\}} \sum_{c \in C} x2_{cj'jvtt'\Omega}}{Q_v} \qquad \forall j \in J \setminus 0, v \in V, t \in T, t' \in T', \Omega \in \Psi \tag{13}$$

$$E_c - t = e_c \qquad \forall c \in C, t = \{1, \dots, T\} \tag{14}$$

$$y_j, z1_{cj}, z2_{cj}, z3_{cj}, U_{kj} \in \{0,1\} \tag{15}$$

$$I1_{cje_ct}, G_{cjt}, E_{cjt}, x1_{cjvtt'\Omega}, x2_{cjj'vtt'\Omega} \geq 0 \tag{16}$$

$$N_{jv}, L1_{ovtt'\Omega}, L2_{jvtt'\Omega} \in Z^+ \tag{17}$$

The objective function presented in Equation (1) indicates the model costs. The costs are related to the variables that belonged to the first stage, which means the variables that are independent of the scenario. Costs include fixed costs to construct local warehouses, costs related to developing the capacity of local warehouses, negative income caused by the exit of medicines before expiration, cost of producing medicines in the manufacturer, fixed and variable costs of transportation, costs related to keeping medicines before occurring the accident and the cost related to expired medicines during the planning horizon.

Constraint (2) defines that each hospital is required to be allocated to one of the local warehouses that is placed in the coverage distance. Constraint (3) shows that it will not be possible to allocate a hospital to a local warehouse if it is not constructed. Constraint (4) local warehouses (except central warehouse) are not allowed to store type A medicines and Constraint (5) explains that purchasing these medicines for local warehouses at the time of the pre-crisis is established zero (it is required to state that the index zero (j = 0) has been considered for the central warehouse).

Constraint (6) indicates that the inventory of medicines with a remaining service life equal to $e_c - 1$ at the end of a period is equal to the inventory of medicines with a remaining service life e_c at the end of the previous period minus the quantity of medicines with a remaining service life e_c that has been removed from the warehouse during the current period. Constraint (7) shows that the stock of medicines with a maximum remaining service life in pre-crisis periods is equal to the purchased amount of these medicines in each period.

Constraint (8) explains that producing medicines in a period is dependent on the capacity of the manufacture for that medicine. Constraint (9) limits the maximum purchase of a medicine per period to the level of capacity determined for that medicine in that warehouse. However, Equation (10) will not consider the capacity level for that warehouse, if a warehouse is not activated.

Constraint (11) explains that a hospital is able to receive medicine from a warehouse, provided that the warehouse be selected as the local warehouse of that hospital. Constraints (12) and (13) determine the minimum number of vehicles needed in the central warehouse and local warehouses in each crisis period and each scenario, respectively by dividing the transported capacity by the vehicles over the capacity of the vehicles. Also, Constraint (14) is as a calendar of the remaining service life of the medicine, and eventually, constraints (15) to (17) identify the type of decision variables in the model.

2. Conclusion

Natural disasters have always been part of our lives. Despite the scientific and technological developments, humans are not able to prevent these events. Several catastrophes and natural disasters such as Tsunamis, floods, earthquakes, and natural disasters, have happened in the last decades (Tavana et al., 2018). Due to the ubiquity of natural disasters around the world, post-disaster crop supply chain disruptions become a challenging global issue (Sheu, 2016).

We studied the modeling of pharmaceutical services that are demanded by the injured people after occurring the crisis and in an integrated perspective with the services and arrangements that local warehouses are able to provide before the crisis. The supply chain model was introduced with the integration of both medicine supply chain decisions and challenges, and logistics and crisis decisions at the time of occurring crisis along with the concerns and demands of injured and damaged populations such as shortages of medicines were examined and studied with the titles of the crisis supply chain, relief or humanitarian items. The supply chain of pharmaceutical items was modeled by considering different decisions such as activating facilities, allocating and conserving pre-crisis inventory (preparation stage), and decisions related to distributing pharmaceutical items and determining the transport fleet to supply pharmaceutical requirements (response stage). The assumptions applied to develop the model, including the allocation of warehouses as central and local warehouses will increase the flexibility of the supply chain and activate facilities adequately.

References

1. Chen, L.M., Liu, Y.E. and Yang, S.J.S. (2015). Robust supply chain strategies for recovering from unanticipated disasters. *Transportation Research Part E: Logistics and Transportation Review*, 77, pp. 198-214.
2. Feili, H.R. (2013). Improving the Health Care Systems Performance by Simulation Optimization. *Journal of Mathematics and Computer Science*, 7, pp. 73-79.
3. Feili, H.R. and Hassanzadeh Khoshdooni, M. (2011). A Fuzzy Optimization Model for Supply Chain Production Planning with Total Aspect of Decision Making. *Journal of Mathematics and Computer Science*, 2(1), pp. 65-80.
4. Feili, H.R., Momeni tabar, M. and Akar, N. (2012). Fuzzy Mathematical Modeling of Distribution Network, Allocation Model Positioning in Three-Level Supply Chain Design. *International Conference on Nonlinear Modeling & Optimization*, Amol, Iran.
5. Habibi-Kouchaksaraei, M., Paydar, M.M. and Asadi-Gangraj, E. (2018). Designing a bi-objective multi-echelon robust blood supply chain in a disaster. *Applied Mathematical Modelling*, 55, pp. 583-599.
6. Noham, R. and Tzur, M. (2018). Designing humanitarian supply chains by incorporating actual post-disaster decisions. *European Journal of Operational Research*, 265 (3), pp. 1064-1077.
7. Samani, M.R.G., Torabi, S.A. and Hosseini-Motlagh, S.-M. (2018). Integrated blood supply chain planning for disaster relief. *International Journal of Disaster Risk Reduction*, 27, pp. 168-188.
8. Sheu, J.-B. (2016). Supplier hoarding, government intervention, and timing for post-disaster crop supply chain recovery. *Transportation Research Part E: Logistics and Transportation Review*, 90, pp. 134-160.
9. Silva, M.E., Pereira, S.C.F. and Gold, S. (2018). The response of the Brazilian cashew nut supply chain to natural disasters: A practice-based view. *Journal of Cleaner Production*, 204, pp. 660-671.
10. Syahrir, I. and Suparno, Vanany, I. (2015). Healthcare and Disaster Supply Chain: Literature Review and Future Research. *Procedia Manufacturing*, 4, pp. 2-9.
11. Tavana, M., Abtahi, A.-R., Di Caprio, D., Hashemi, R. and Yousefi-Zenouz, R. (2018). An integrated location-inventory-routing humanitarian supply chain network with pre-and post-disaster management considerations. *Socio-Economic Planning Sciences*, 64, pp. 21-37