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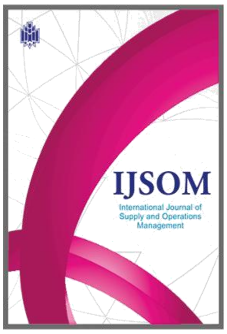

Designing Sustainable Distribution Network in Pharmaceutical Supply Chain: A Case Study

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Abstract
In order to compete effectively in the international markets, pharmaceutical companies must improve their competency. They need to select certain levels of commitment for sustainability practices to sustain their supply chains. This research presents a multi-objective model to design a pharmaceutical distribution network according to the main concepts of sustainability, i.e. economic, environmental, and social. This model helps managers to make strategic and technical decisions in the pharmaceutical distribution network (capacity of main and local distribution centers and the flow of drug in the network). Minimizing the costs and maximizing the welfare of society along with minimizing the adverse environmental effects lead to sustainable decisions. The NSGA-II algorithm was also applied to catch the Pareto-optimal front for the proposed model with respect to three objective functions. To test the model with real data, Darupakhsh Distribution Company was chosen. The results of the customized model for the case reveal the strategic and technical decisions in the pharmaceutical distribution network.

Keywords: Pharmaceutical supply chain; Distribution network; Sustainability; Multi-objective decision making; Non-dominated sorting genetic algorithm.

1. Introduction

Designing sustainable supply chains, companies must review the impact of supply chain operations on the environment and society because of the increasing environmental, legislative, and social considerations (Govindana et al., 2013). The World Commission on Environment and Development (WCED) defines a sustainable development as “a development that satisfies the current requirements without compromising the ability of future generations to meet their own requirements” (Brundtland, 1987). Sustainability is based on economic, environmental, and social dimensions for man development (Ageron et al., 2012; Gopalakrishnan et al., 2012). Many companies have selected certain levels of commitment for sustainability practices to sustain their supply chains. Academia and various industries of the global economy have implemented sustainability initiatives such as “energy efficient technologies, the use of renewable sources, recycling, green procurement, reduced packaging, carbon emission accounting, social responsibilities, and employee recognition” to ensure sustainability in supply chain management (Gopalakrishnan et al., 2012). Some studies focus on the environmental aspect while the social aspect of the supply chain still remains neglected (Silvestre, 2016).

Pharmaceutical firms are basically forced by the powerful regulatory and market forces to rethink the way they produce and distribute products, and they are also made to reimagine the role of the supply chain in driving strategic growth, brand differentiation, and economic value in the health system (Mehralian et al., 2012). The pharmaceutical supply chain needs more consideration compared with other industries such as Customized demand of customers, market dynamic factors, weak networks and governmental policies (Vishwakarma et al., 2016). Assuring the continuous flow of drugs to patients at optimal prices and with minimal delays, low shortages with no errors is valuable in pharmaceutical supply chains (Mehralian et al., 2016). The purpose of this study is to design a pharmaceutical distribution network according to the main

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concepts of sustainability, i.e. economic, environmental, and social. This model helps to make the strategic and technical decisions in the pharmaceutical distribution network as decisions about the capacity of main distribution centers as well as the number and capacity of local distribution centers. These decisions are made to minimize the costs as well as the adverse environmental effects along with maximizing the welfare of society.

The rest of the paper is organized as follows: Section 2 presents the distribution in sustainable pharmaceutical supply chain and the significant studies relating to this research. In Section 3, a mathematical model consisting of parameters, variables, objective functions, and operational constraints is developed. The solution approach to the sustainable pharmaceutical network model is described in Section 4. To check this model with a real data, one of the main pharmaceutical distribution companies in Iran is chosen and then the model is customized with the conditions of this company in Section 5. Finally, Section 6 presents the results and conclusions of the research and suggests some potential works as future studies in the field.

2. Distribution in the sustainable pharmaceutical supply chain

Pharmaceutical expenditures are constantly increasing so that the pharmaceutical section has a significant share of any national gross domestic product (GDP) these days. In order to compete in both domestic and international markets, pharmaceutical companies are under pressure to create situations that enable them to grow (Mehralian et al., 2016). So, investigation into pharmaceutical supply chain area is necessary for all countries (Ahmadi et al., 2018). As shown in Figure 1, a pharmaceutical supply chain is typically composed of one or more of the following sections: (i) primary manufacturing including contractor sites; (ii) secondary manufacturing including contractor sites; (iii) market warehouses or distribution centers; (iv) wholesalers; and (v) retailers or hospitals (Yu et al., 2010). The primary manufacturing produces active materials involving chemicals to construct the molecules. The secondary manufacturing includes further processes on products received from the active ingredient manufactured at the primary site and, ultimately, packaging to present final products. Wholesalers have a major role in this section (Shah, 2004).

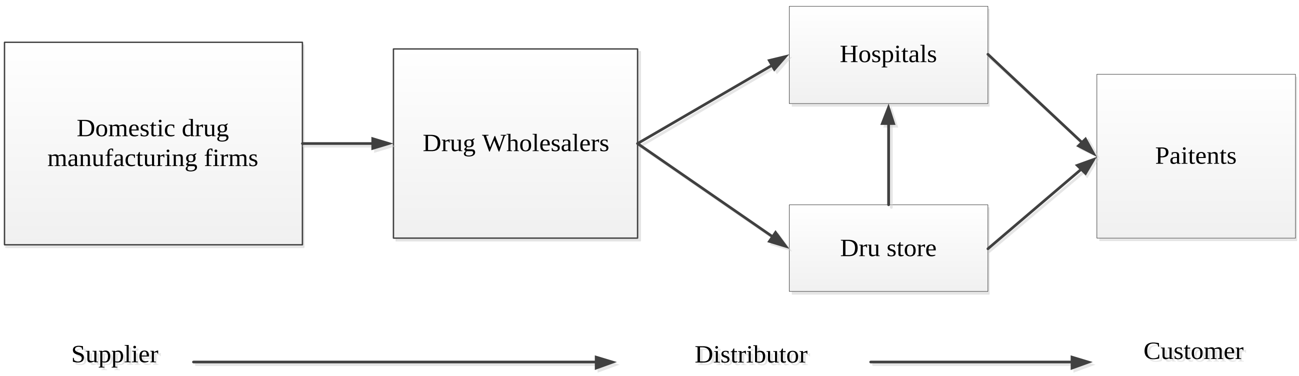

Figure 1. Pharmaceutical supply chain components (Mehralian et al., 2012)

The pharmaceutical supply chain network is multi-product and multi-period. It also has a four-echelon pharmaceutical supply chain that includes many secondary drug manufacturing centers, main distribution centers (DCs), local distribution centers (DCs), as well as customer zones (i.e., hospitals, clinics and pharmacies) with transshipment drugs between local distribution centers (Mousazadeh et al., 2015).

Asamoah et al. (2012) studied the pharmaceutical industry and presented a good methodology for the evaluation and selection of suppliers in a pharmaceutical firm in Ghana. The study sought specifically to use the analytic hierarchy process methodology to choose the most appropriate raw material suppliers of the anti-malarial drug as the case study. Meijboom and Obel (2007) studied the internal supply chain of an international pharmaceutical company characterized by a multi-location and multi-stage operation structure. They addressed issues at three levels, namely the strategic, tactical, and operational levels. They focused on the tactical level, identified a model along with a case that captured the strategic and tactical issues, and related the tactical issues to organizational subjects.

Hassani et al. (2014) proposed a total optimization model to maximize the profit of a closed-loop global supply chain for medical devices under uncertainty. This model considers several realistic assumptions pertaining to medical device supply chains such as multiple products, multiple periods, multiple echelons, and limited warehousing life cycle. Thus, reverse flows of perished and defective products are expected to consider environmental concerns and customers' requirements as well as gain economic advantages. To solve this problem, an efficient memetic algorithm with adaptive variable neighborhood search as its local search heuristic was developed. Mousazadeh et al. (2015) proposed a bi-objective mixed integer linear programming model for a pharmaceutical supply chain network design problem. This model suggests making several decisions about the strategic issues such as opening pharmaceutical manufacturing centers as well as main or local distribution centers with optimal material flows over a mid-term planning horizon as the tactical decisions. It minimizes the total costs and unfulfilled demands as the first and second objective functions. To check the validity of the proposed model, it was evaluated based upon a real case study (the supply chain network design of Amoxicillin 500mg Cap in Iran). Finally, two well-known multi-objective decision making techniques, i.e., the ε-constraint method and the TH approach, were applied to receive both trade-off surface and final preferred compromise solution for the real case study. Finally, the results were analyzed comprehensively.

To address the inconsistent definitions of sustainability in the literature on supply chain management, Carter and Rogers (2008) applied the concept of "true sustainability". They suggested that the consideration of environmental and social issues should be "coupled with economic objectives" and cooperate in the company's strategic long-term planning. From the strategic viewpoint, Mota et al. (2014) stated this research question: "How can sustainability be integrated into supply chains' design and planning decisions?" Several methods and frameworks have been proposed to assess environmental impacts. However, life cycle assessment has been described as the most scientifically reliable solution available for studying and evaluating the environmental effects of a certain product or process, allowing both backward and forward assessment (Ness et al., 2007).

One of the important challenges for today's manufacturing companies is measuring and controlling CO_2 emissions across the logistics network because of the increasing concern about the environmental impact of business activities. Pishvaee et al. (2012) designed a bi-objective credibility-based fuzzy mathematical programming model for the strategic configuration of a green logistics network under uncertain circumstances. The model minimizes the environmental impacts and the total costs of network organization simultaneously to create a balance between them. A popular and credible environmental impact assessment index, i.e., CO_2 equivalent index, was used to model the environmental impact through the concerned logistics network. Since transportation mode and production technology play the important roles for the concerned objectives, Pishvaee et al. (2012) integrated their respective decisions with those of strategic network design ones. To solve the proposed bi-objective fuzzy optimization model, an interactive fuzzy solution approach was developed based upon credibility measures.

The Global Reporting Initiative (GRI) describes the social dimension of sustainability as one that **"**concerns the organization impacts on the social systems within which it operates**"** (2013). The importance of this pillar of sustainability is clear. Still there is a huge deficit in the amount of published literature on social impact assessment (Brandenburg et al., 2014), mostly due to the difficulty in measuring such impacts (Zhao et al., 2012). The sustainability reporting guidelines (GRI, 2013) help organizations to measure their performance within the three dimensions of sustainability. "Due to its ease of use and comprehensiveness, it is now commonly used by companies to report and monitor their evolution on sustainable issues" (Roca and Searcy, 2012). In these guidelines, the social aspect is divided into four categories: Labor practices and decent work, society, human rights, and product responsibility.

Societies and governments are forcing companies to become more sustainable. Accordingly, Mota et al. (2014) designed a generic multi-objective mathematical programming model for planning supply chains and integrating the three dimensions of sustainability. The economic aspect of sustainability addressed in this work is the consideration of the costs of the supply chain. Then ReCiPe (an environmental assessment methodology) was indicated in the literature for the first time, and it was applied to supply chain design optimization. Finally, Mota et al. (2014) proposed a social indicator that is appropriate for assessing strategic decisions. This social indicator considers the impact of both social and political issues on the company's performance. This research was tested in the real case study of a Portuguese battery producer and distributor.

3. Designing the sustainable distribution network

The growing environmental competition shifts firms from corporate-level to supply-chain level competition. "The challenge of incorporating comprehensive sustainability goals into corporate behavior" (Gold et al. 2010) forces the supply chains to be sustainable in global markets. Recently, a considerable improvement to support pharmacy product distribution is achieved with the help of the advanced computerized technology so that it can handle the dispensation of medications and automate the system of ordering, so the pharmaceutical section needs available information to help managers with making proper decisions and monitor supply chain management. These decisions include determining strategic problems like opening pharmaceutical manufacturing centers as well as main or local distribution centers along with the optimal material flows over a mid-term planning horizon for tactical decisions. Figure 2 shows the distribution sector in the pharmaceutical supply chain (Mousazadeh et al., 2015).

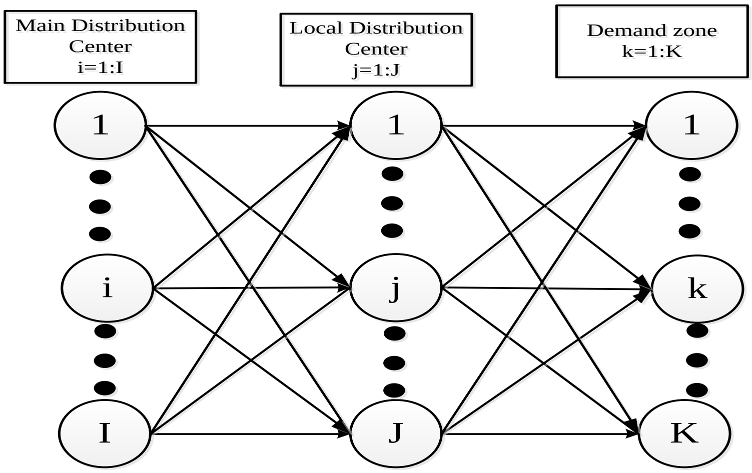

Figure 2. Distribution network in the pharmaceutical supply chain

The purpose of this research is to design a distribution network of medicine considering three objectives of sustainability i.e. social, environmental and economic aspects. The model proposed later is inspired by three models developed by Mousazadeh et al. (2015), Pishvaee et al. (2012), and Mota et al. (2014). The following sets and indices, parameters, and decision variables are used to formulate the problem mathematically:

Sets and indices

h	Index of transportation modes; $h \in \{1,2,\dots,H\}$
i	Index of candidate locations of main distribution centers; $i \in \{1,2,\dots,I\}$
j	Index of candidate locations of local distribution centers; $j \in \{1,2,\dots,J\}$
k	Index of customer's location; $k \in \{1,2,\dots,K\}$
n	Index of possible capacity levels of main distribution centers; $n \in \{1,2,\dots,N\}$
p	Index of product family; $p \in \{1,2,\dots,P\}$
t	Index of periods of time; $t \in \{1,2,\dots,T\}$

Parameters

a_{ijp}^{h}	Unit transportation cost of product family p from main distribution center i to local distribution center j by transportation mode h
d_{kpt}	Demand of customer zone k for product family p at period t
e_{jkp}^{h}	Unit transportation cost of product family p from local distribution center j to customer zone k by transportation mode h
g_i^n	Fixed cost of opening main distribution center i with capacity level n
b_j	Fixed cost of opening local distribution center j
SC_{ip}	Unit storage cost of product family p at the end of each period in main distribution center i
SC'_{jp}	Unit storage cost of product family p at the end of each period in local distribution center j
δ_i^n	Storage capacity of main distribution center i established by capacity level n
γ_j	Storage capacity available at local distribution center j
π_p	Relative importance of product family p
θ_i	Regional factor (unemployment ratio) in main distribution center i
$\acute{\theta}_j$	Regional factor (unemployment ratio) in local distribution center j
η_i	The number of jobs created at main distribution center i
$\acute{\eta}_j$	The number of jobs created at local distribution center j
C_{ijp}^{h}	CO_2 equivalent emission per unit product of family p shipped from main distribution center i to local distribution center j by transportation mode h
$\acute{C}_{jkp}^{h}$	CO_2 equivalent emission per unit product of family p shipped from local distribution center j to customer zone k by transportation mode h

Decision variables

I_{ipt}	Inventory level of product family p at main distribution center i at the end of period t
$\acute{I}_{jpt}$	Inventory level of product family p at local distribution center j at the end of period t

o_{jkpt}^{h} Quantity of product family p shipped from local distribution center j to customer k in period t using transportation mode h

q_{ijpt}^{h} Quantity of product family p shipped from main distribution center i to local distribution center j in period t using transportation mode h

z_j $\begin{cases} 1 \text{ if potential local distribution center } j \text{ is opened} \\ 0 \text{ otherwise} \end{cases}$

y_i^n $\begin{cases} 1 \text{ if potential main distribution center } i \text{ with capacity level } n \text{ is opened} \\ 0 \text{ otherwise} \end{cases}$

The mathematical model

$$Min\, w_1 = \sum_{i,n} g_i^n y_i^n + \sum_{j} b_j z_j + \sum_{i,j,h,p,t} a_{ijp}^h q_{ijpt}^h + \sum_{j,k,h,p,t} e_{jkp}^h o_{jkpt}^h + \sum_{i,p,t} SC_{ip} I_{ipt} + \sum_{j,p,t} S\acute{C}_{jp} \acute{I}_{jpt} \quad (1)$$

$$Min\, w_2 = \sum_{i,j,h,p,t} C_{ijp}^h q_{ijpt}^h + \sum_{j,k,h,p,t} {C'}_{jkp}^{h} o_{jkpt}^h \quad (2)$$

$$Max\;\; w_3 = \textstyle\sum_{i,n} \theta_i \eta_i y_i^n + \sum_j {\theta'}_j {\eta'}_j\, z_j \quad (3)$$

Subject to:

$$I'_{jpt} = I'_{jpt-1} + \sum_{i,h} q_{ijpt}^h - \sum_{k,h} o_{jkpt}^h \;; \forall\, j, p, t \quad (4)$$

$$\sum_{P} I_{ipt} \;\; \leq \sum_{n} \delta_i y_i^n \;; \forall\, i, t \quad (5)$$

$$\sum_{p} \left(I'_{jpt-1} + \sum_{j,h} q_{ijpt}^h \right) \leq \gamma_j z_j \quad ; \forall j, t \quad (6)$$

$$\sum_{j,h} o_{jkpt}^h \;\geq d_{kpt}\; \forall\, k, p, t \quad (7)$$

$$\sum_{n} y_i^n \leq 1 \;; \forall i \quad (8)$$

$$y_i^n, z_j \in \{0,1\}\,, \forall i, j \quad (9)$$

$$q_{ijpt}^h, o_{jkpt}^h, I_{ipt}, I'_{jpt}, \geq 0, \quad \forall i, j, k, h, p, t \quad (10)$$

The model proposed in this research belongs to multi-objective decision-making problems and has three objectives. Unlike the model proposed by Mousazadeh et al. (2015), the first objective function presented by Eq. (1) and focused on the economical aspect of sustainability minimizes the costs in each stage. These costs include the costs of opening main and local DCs, the transportation costs of drugs from main DCs to local DCs, transportation costs of drugs from local DCs to customers, and the storage costs of each DCs. The second objective function presented by Eq. (2) is focused on the environmental aspect of sustainability, which is inspired by Pishvaee et al. (2012)'s research. This function minimizes the amount of CO_2 emission of transporting drugs from main DCs to local DCs and local DCs to customers. The third objective function presented by Eq. (3) is the social aspect of sustainability, which is inspired from Mota et al. (2014)'s research. The third objective function maximizes the job creation in less developed regions. This objective function chooses the main and local DCs that have higher priorities to create jobs. It means that the DC with the high rate of unemployment as the regional factor or more labor need has a better chance to be chosen in this process. Constraints (4) through (10) present the operational constraints of this research problem. The initial assumption of this model is that there is no connection among either main distribution centers or local distribution centers. Constraint (4) indicates the flow balance of each product family at each local distribution center in each period. The inventory level at local DC j at the end of period t equals the inventory level of previous period and the quantity of the drug that is received from main DCs minus the quantity of the drug that is sent to local DCs. Constraints (5) and (6) imply storage capacity constraints for the main and local distribution centers, respectively. The inventory levels of main and local DCs must not be greater than the capacity of each DC. Constraint (7) ensures that the flow of each product to the customer zone can fulfill the demand of each zone. Choosing one capacity level for each opened main distribution center is guaranteed by constraint (8). Finally, constraints (9) and (10) show the type of decision variables.

4. Solution approach

The aforementioned model provides a solution of compromise between economic, environmental and social impacts; this work also encompasses a multi-objective approach. As described in the following Eq. (11), the purpose is to minimize the costs and environmental effects, i.e., $f_1(x), f_2(x)$, as well as maximize social benefits, i.e., $f_3(x)$, where x is the vector of decision variables and S is the feasible region.

$Min\ (f_1(x), f_2(x))$

$Max\ f_3(x)$

s.t

$x \in S$ (11)

The drawback of multi-objective decision making methods like the weighted sum or ε-constraint technique is that they present just one optimal solution. Optimizing a set of objectives at the same time gives a set of optimal solution instead of a single solution. Therefore, if the model has more than one optimal solution, these methods are not able to present them. Hence, if a method gives a large number of alternative solutions on or close to the Pareto-optimal front, it is valuable. Over the past decade, some multi-objective evolutionary algorithms (MOEAs) have been proposed to deal with multi-objective problems. These methods have the ability to find multiple Pareto-optimal solutions in one single run (Deb et al., 2000). This is the case, NSGA-II algorithm is proposed which is a fast non-dominated sorting genetic algorithm. NSGA-II has the computational complexity in order mn^2, where m represents the number of objectives and n represents the number of population (*npop)*.

Compared with other MOEAs algorithms, the main advantages of this algorithm are low computational requirements, elitist approach, and parameter-less sharing method. Therefore, NSGA-II algorithm is applied to obtain Pareto-optimal solutions since it is a fast elitist non-dominated sorting genetic algorithm for multi-objective optimization. NSGA-II proposed by Deb et al. (2000) criticizes the non-dominated sorting genetic algorithm (NSGA) proposed by Srinivas and Deb (1995) so that it reduces all difficulties in the basic NSGA.

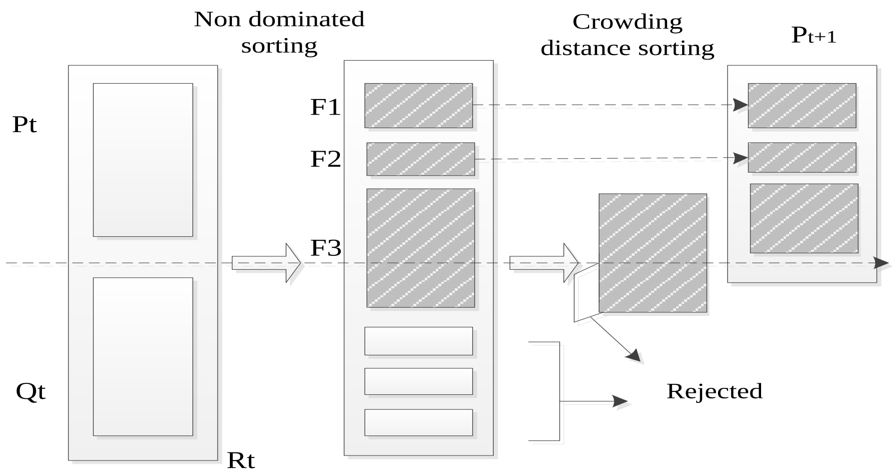

Figure 3. The schematic of NSGA-II algorithm (Yandamuri et al., 2006)

The schematic of NSGA-II algorithm is depicted in Figure 3. Deb et al. (2000) indicated the steps of this algorithm as follows:

1- The random parent population (p_0) of size *n* is created, initially.

2- The initial random parent population based on the non-dominated concept is sorted.

3- For each non-dominated solution, a fitness (rank) equal to its non-dominated level is assigned (1 is for the best level, and so on).

4- The child population (Q_0) of size *n* using binary tournament selection, recombination, and mutation operators is created.

5- The set (R_t) of size 2n by combining the parent population (P_t) and the child population (Q_t) is created.

6- The combined population set (R_t) according to the fast non-dominated sorting procedure to identify all non-dominated fronts ($F_1, F_2, \ldots, F_L$) is sorted.

7- The new parent population (P_{t+1}) of size n by adding non-dominated solutions starting from the first ranked non-dominated front (F_1) and proceeding with the next ranked non-dominated fronts (F1, F2, . . ., FL), until the size exceeds n is generated. The total count of the non-dominated solutions from the fronts $F_1, F_2, \ldots F_L$ exceeds the population size n. It is necessary to reject some of the lower ranked non-dominated solutions from the last (F_L^{th}) front. The crowded comparison operator ($\geq n$) based on the crowding distance assigned to each solution contained in the F_L^{th} non-dominated front will be done. Thus, the new parent population (P_{t+1}) of size n is constructed.

8- To create the new child population (Q_{t+1}) of size n, the selection, crossover and mutation operations on the newly generated parent population (P_{t+1}) are performed.

9- Until the maximum number of generations is satisfied the step5-8 are repeated (Murty et al., 2006).

5. Experimental Study

In the following, the proposed sustainable distribution network model in pharmaceutical supply chain is customized for a real case study in Iran. The pharmaceutical distribution Darupakhsh Company, which is one of the main pharmaceutical distribution companies in Iran, was chosen to apply the model. The investigation of this company shows that it has one main distribution center located in Tehran and 20 local distribution centers in other cities of Iran. One of the strategic drugs was selected according to Darupakhsh Company experts' opinion. The required data were collected from 20 important customers of this drug (Clopidogrel drug). The possible structure of the distribution network for the experimental study (Clopidogrel drug) is shown in Figure 4.

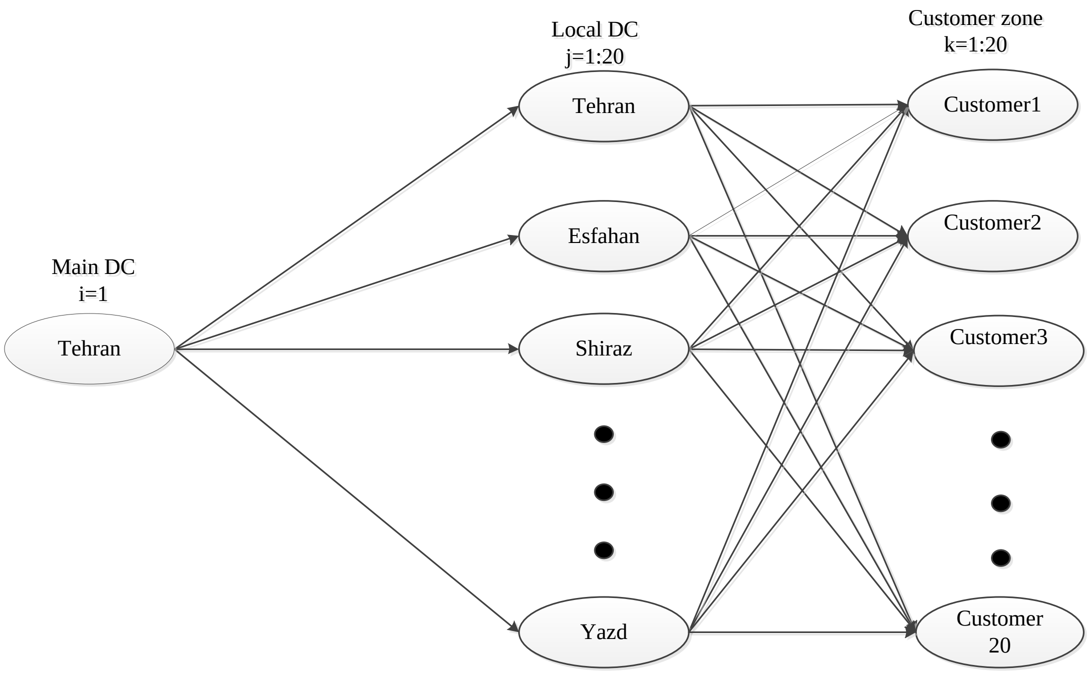

Figure 4. The Possible structure of the distribution network for the experimental study (Clopidogrel drug)

The design of the distribution network for the experimental study (Clopidogrel drug) is based on the data collected from the pharmaceutical distribution company in Iran. The assumptions of this experimental study are defined as follows:

I. Clopidogrel drug is chosen based on experts' opinion $\Rightarrow p = 1$.
II. The data is collected during one year $\Rightarrow t=1$.
III. There is one transportation mode (truck) in this pharmaceutical distribution company $\Rightarrow h=1$.
IV. There is one main distribution center for Clopidogrel drug with one capacity $\Rightarrow i = 1$ and $n=1$.
V. The inventory level of Clopidogrel drug at the beginning of the period in main and local distribution centers is zero.

The data on the fixed cost of opening main distribution center, the fixed cost of opening local distribution centers, the demand data of customer zones, storage capacities of main and local distribution centers, and other required data are obtained for Clopidogrel drug, Darupakhsh Distribution Company. Table 1 through 4 show the required data for modeling. In the next step, the unit transportation cost per 100 km via truck is obtained through "consulting shipping agencies". The distance between each two locations is estimated using "Google map". Then, the unit transportation cost between each pair of locations needed is calculated. This study considers the CO_2 equivalent index for truck, which is a transportation mode, based on the Eco-indicator 99 databases in the model formulation. The CO_2 equivalent index is a credible index that can simply quantify the environmental impact and has already been used by researchers (Pishvaee et al., 2012). The third objective needs the unemployment ratio of each local distribution center city and the number of jobs created at local distribution centers. The data of unemployment ratio 2016 is gathered from the Statistical Center of Iran. Other parameters that are not reported here can be provided upon request.

Table 1. The fixed cost of opening local DCs (in billion Rials)

Local DCs	Fixed cost of opening	Local distribution centers	Fixed cost of opening
Tehran1	60	Ardebil	1.7
Tehran2	48	Sari	16
Esfahan	66	Yazd	15
Shiraz	35	Tabriz	27
Rasht	15	Hamedan	19
Orumiyeh	17	Mashhad	40
Bandarabbas	13	Kerman	20
Ahvaz	24	Gorgan	17
Zahedan	37	Kermanshah	43
Bushehr	4	Qom	11

Table 2. The Clopidogrel drug's demands of customer zones (2016)

Customer zone	Demand (box) per year	Customer zone	Demand (box) per year
Customer 1	7400	Customer 11	12910
Customer 2	9020	Customer 12	5355
Customer 3	4817	Customer 13	7641
Customer 4	4725	Customer 14	3910
Customer 5	15328	Customer 15	1152
Customer 6	10480	Customer 16	7794
Customer 7	10140	Customer 17	7284
Customer 8	14052	Customer 18	6484
Customer 9	14397	Customer 19	7734
Customer 10	5822	Customer 20	2510

Table 3. The Regional factor (unemployment ratio) local DCs

Local distribution centers	Regional factor (Unemployment ratio %)	Local distribution centers	Regional factor (Unemployment ratio %)
Tehran1	13.3	Ardebil	12.6
Tehran2	13.3	Sari	10.8
Esfahan	17.4	Yazd	11.8
Shiraz	13.6	Tabriz	10.4
Rasht	9.9	Hamedan	8
Oroomieh	7.5	Mashhad	12.5
Bandarabbas	10.8	Kerman	11.9
Ahvaz	14.9	Gorgan	12.8
Zahedan	13.8	Kermanshah	20.3
Bushehr	11.2	Qom	11.4

Table 4. The number of labors needed at local DCs

Local distribution centers	Number of labors needed	Local distribution centers	Number of labor needed
Tehran1	90	Ardebil	10
Tehran2	80	Sari	40
Esfahan	50	Yazd	30
Shiraz	50	Tabriz	50
Rasht	30	Hamedan	30
Oroomieh	30	Mashhad	60
Bandarabbas	30	Kerman	30

Table 4. Continued

Local distribution centers	Number of labors needed	Local distribution centers	Number of labor needed
Ahvaz	40	Gorgan	30
Zahedan	30	Kermanshah	30
Bushehr	10	Qom	30

In order to solve the proposed model with a real case study in Iran, the weighted sum method is first used to better depict the controversial nature of the objective functions and provide a suitable approximation of the Pareto frontier for the decision makers while it does not lead to a single solution. The solution of this model will determine these issues: local distribution centers that must be opened; the quantity of Clopidogrel drug sent from the main distribution center to local distribution centers; and the amount of Clopidogrel drug transferred to customer zones (Table 5).

In the next step of the study, the NSGA-II algorithm was applied to obtain the Pareto-optimal front for the proposed model with three objective functions. The main distinction between NSGA-II and GA is the sorting process. The sorting process is in accordance with the rank and crowding distance. The complexity of NSGA-II algorithm for this model is $3 \times npop^2$. The best solutions in Pareto front are 12 optimal points in one run, which is illustrated in Figure 5. The red stars in Figure 5 show the optimum amount of objective functions in a run. In this run *npop* is 50 with 300 iterations.

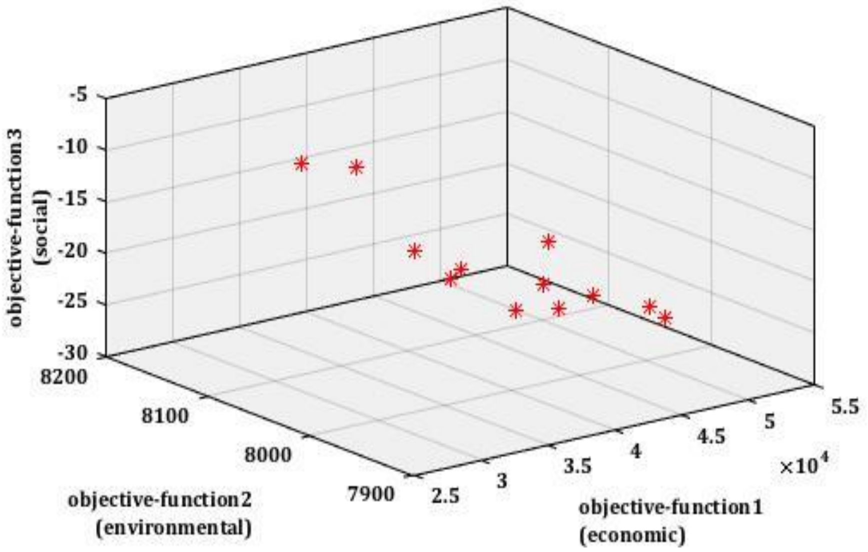

Figure 5. The optimal amounts of objective functions in Pareto front in one run

Based on 12 solutions obtained, the experts can compare the solutions and choose the best answer according to the company policy on considerations and discretions. Each solution demonstrates active local distribution centers, the quantity of Clopidogrel drug transferred from the main distribution center to the local distribution centers, and the quantity of Clopidogrel drug transferred from the local distribution centers to the customer zones. Tables 5 and 6 show the first result of Pareto front in one run. Following the same procedure, the other 11 solutions can be obtained.

Table 5. Quantity of drug Y shipped from the main distribution center to local distribution centers for an example point in Pareto front

DC1 (Tehran1)	14300
DC2 (Tehran2)	15000
DC5 (Rasht)	12289
DC6 (Orumiyeh)	21776
DC8 (Ahvaz)	19205
DC9 (Zahedan)	8991
DC13 (Yazd)	21800
DC16 (Mashhad)	14817
DC17 (Kerman)	6651
DC18 (Gorgan)	8816
DC19(Kermanshah)	8369
DC20 (Qom)	6941

Table 6. Quantity shipped from the local DC to the customer zone for an example point in Pareto front

Best solution	An example point in Pareto front Quantity shipped from the local DC to the customer zone											
Local Dc active	DC1 (Tehran 1)	DC2 (Tehran 2)	DC5 (Rasht)	DC6 (Orumiyeh)	DC8 (Ahvaz)	DC9 (Zahedan)	DC13 (Yazd)	DC16 (Mashhad)	DC17 (Kerman)	DC18 (Gorgan)	DC19 (Kermanshah)	DC20 (Qom)
Customer 1	410	2400	0	290	0	500	0	0	1500	500	1800	0
Customer 2	0	5000	0	400	2500	100	400	0	0	500	120	0
Customer 3	0	450	1000	0	1500	150	0	0	150	0	200	1367
Customer 4	0	1230	0	1490	0	345	540	0	470	0	0	650
Customer 5	2000	0	2500	1300	3500	0	350	0	0	4020	1080	578
Customer 6	1050	0	1300	540	2200	1300	1300	1200	130	250	670	540
Customer 7	0	560	0	0	300	210	2100	2100	1200	2100	1250	320
Customer 8	4760	0	450	768	324	530	3200	3200	320	100	60	340
Customer 9	450	0	980	6579	496	2122	870	560	490	350	700	800
Customer 10	0	0	1000	320	1200	569	498	890	671	200	150	324
Customer 11	1340	2010	340	3500	900	1230	1200	1600	0	120	190	480
Customer 12	1200	0	1250	200	560	600	495	670	300	0	80	0
Customer 13	1728	0	1200	579	1000	495	1800	560	0	49	230	0
Customer 14	1320	1400	0	0	0	0	0	290	900	0	0	0
Customer 15	0	0	0	600	0	420	0	0	0	42	90	0
Customer 16	15	1250	2000	450	0	150	1500	1390	100	150	789	0
Customer 17	27	0	0	1000	2700	270	2700	457	130	0	0	0
Customer 18	0	0	269	3200	1000	0	0	0	0	65	750	1200
Customer 19	0	0	0	560	1025	0	4287	700	290	320	210	342
Customer 20	0	700	0	0	0	0	560	1200	0	50	0	0

6. Conclusion

Today, pharmaceutical expenditures are increasing and this section has a significant share of any national GDP. In order to compete in both domestic and international markets, pharmaceutical companies are under pressure to create situations that enable them to grow and compete. Another change in global competition is that companies select certain levels of commitment for sustainability practices to sustain their supply chains. This research presented a multi-objective model to design a pharmaceutical distribution network according to the main concepts of sustainability i.e. economic, environmental and social. The first objective function was related to costs, and the purpose was to minimize the costs of transporting the products from main distribution centers to local distribution centers and from local distribution centers to customer zones. The second purpose was to reduce the CO_2 emissions from the distribution network. The third objective function was to maximize the social welfare (i.e. increase the rate of employment) in the pharmaceutical distribution network.

Because of the advantages of NSGA-II method (low computational requirements, elitist approach, and parameter-less sharing method) that are indicated in the literature, this technique is used to achieve the best solution. One of the main pharmaceutical distribution companies in Iran, Darupakhsh Distribution Company is chosen to apply the model. The best solutions in Pareto front were 12 optimal points and mangers chose the best answer according to the company policy on the considerations and discretions. This solution determined the active local distribution centers, the quantity of Clopidogrel drug transferred from the main distribution center to the local distribution centers, and the quantity of Clopidogrel drug transferred from the local distribution centers to the customer zones. For example, 19205 boxes of this drug must be transferred to Ahvaz (DC8). The Ahvaz distribution center will send 2500, 1500 and 3500 boxes of Clopidogrel drug to customer 2, customer 3 and customer 5, respectively. The results of the customized model in the case show the strategic and technical decisions in the pharmaceutical distribution network. Decisions about the capacities of main distribution centers, the number of local distribution centers, and their capacities are the output of solving the proposed model. The model helps managers to decide the best location of new distribution centers according to three aspects of sustainability. The selection of main and local distribution centers through this sustainable model aids managers of pharmaceutical distribution companies to minimize the costs. Also, it may minimize the emission of CO_2 and have environmental advantages. The results of this study could be useful for the societies with high unemployment rate. The third objective function assists with choosing the distribution centers that need more labor. The designed model for the pharmaceutical distribution network could be used for other distribution networks that have main and local distribution centers and have the same connections among them like perishable goods distribution networks. Some accelerator assumptions are considered in this paper. The uncertainty of environment is not considered. This model only considers the CO_2 emissions in the environment. There are more effects recognized in this aspect like the energy used per product. In this study, the rate of employment is considered for optimizing the social aspect of sustainability, but other factors like labor practices, decent work, society, human rights, and product responsibility are recognized too. Suggestions for further studies include testing the model for other drugs and in uncertain circumstances, as well as substituting other indicators of environmental and social aspects of sustainability in the objective functions of the model. Solving this model with other algorithms could be useful for comparing the results in future studies.

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References

Ahmadi A., Mousazadeh M., Torabi S. A. and Pishvaee M. S. (2018). OR Applications in Pharmaceutical Supply Chain Management. *International Series in Operations Research and Management Science*, Vol. 262, pp.461–491.

Ageron B., Gunasekaran A. and Spalanzani A. (2012). Sustainable Supply Management: An Empirical Study. *International Journal of Production Economics*, Vol.140 (1), pp. 168-182.

Asamoah D., Annan J. and Nyarko, S. (2012). AHP Approach for Supplier Evaluation and Selection in a Pharmaceutical Manufacturing Firm in Ghana. *International Journal of Business and Management*, Vol.7 (10), pp.49-62.

Brandenburg M., Govindan K. Sarkis J. and Seuring S. (2014). Quantitative models for sustainable supply chain management: developments and directions. *European Journal of Operational Research*, Vol.233 (2), pp.299-312.

Brundtland G.H. (1987). Our common future. Oxford paperbacks report. (A/42/427).

Carter C. R. and Rogers D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management*, Vol.38 (5), pp.360-387.

Deb K., Agrawal S., Pratap A. and Meyarivan T. (2000). A Fast Elitist Non-Dominated Sorting Genetic Algorithm for Multi-Objective Optimization: NSGA-II. *Lecture Notes in Computer Science 1917*, pp.849-858.

Gold S., Seuring S. and Beske, Ph. (2010). Sustainable supply chain management and inter-organizational resources: a literature review. *Corporate Social Responsibility and Environmental Management*, Vol.17 (4), pp.230-245.

Gopalakrishnan K., Yusuf A., Abubakar T. and Ambursa H. (2012). Sustainable supply chain management: A case study of British Aerospace (BAe) Systems. *International Journal of Production Economics*, Vol.140 (1), pp.193–203.

Govindana k., Khodaveric R. and Jafarian A. (2013). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*, Vol. 47 (5), pp.345–354.

GRI, (2013). G4 Sustainability Reporting Guidelines. Global Reporting Initiative, Amsterdam.

Hassani A., Zegordi S.H. and Nikbakhsh, E. (2014). Robust closed loop global supply chain network design under uncertainity: the case of the medical device industry. *International Journal of Production Research*, Vol.53 (5), pp.1-30.

Marler R. T. and Jasbir S.A (2010). The weighted sum method for multi-objective optimization: new insights. *Structural and Multidisciplinary Optimization*, Vol.41 (6), pp.853–862.

Mehralian Gh., Rajabzadeh A., Morakabati M. and Vatanpour H. (2012). Developing a Suitable Model for Supplier Selection Based on Supply Chain Risks: An Empirical Study from Iranian Pharmaceutical Companies Services. *Iranian Journal of Pharmaceutical Research*, Vol.11 (1), pp.209-219.

Mehralian Gh., Nazari J. A., Rasekh, H. R. and Hosseini S. (2016). TOPSIS approach to prioritize critical success factors of TQM: evidence from the pharmaceutical industry.*The TQM Journal*, Vol. 28 (2), pp.235-249.

Meijboom B. and Obel B. (2007). Tactical coordination in a multi-location and multi-stage operations structure: A model and a pharmaceutical company case. *Omega*, Vol.35, pp.258–273.

Mota B., Gomes Ke., Carvalho A., and Barbosa-Povoa A. (2014). Towards supply chain sustainability: economic, environmental and social design and planning. *Journal of Cleaner Production*, Vol.107, pp.14–27.

Mousazadeh M., Torabi S.A. and Zahiri B. (2015) .A robust Possibilistic Programming approach for pharmaceutical supply chain network design. *Computers and Chemical Engineering*, Vol. 82, pp.115-128.

Ness B., Urbel-Piirsalu E., Underberg S. and Olsson L. (2007). Categorizing tools for sustainability assessment. *Ecological Economics*, Vol.60, pp.498-508.

Pishvaee M.S., Torabi S.A. and Razmi J. (2012). Credibility-based fuzzy mathematical programming model for green logistics design under uncertainty. *Computers and Industrial Engineering*, Vol.62, pp. 624–632.

Roca L.C. and Searcy C. (2012). An analysis of indicators disclosed in corporate sustainability reports. *Journal of Cleaner Production*, Vol.20 (1), pp.103-118.

Shah N. (2004). Pharmaceutical supplies chains: key issues and strategies for optimization. *Computers Chemical Engineering*, Vol.28, pp.929–941.

Silverstra B. (2016). Sustainable supply chain management: current debate and future directions, Gest and Prod,sao carlos, Vol.23 (2), pp.235-349.

Srinivas N. and Deb, K. (1995). Multi-Objective function optimization using non-dominated sorting genetic algorithms. *Evolutionary Computation*, Vol.2 (3), pp.221-248.

Vishwakarma V., Prakash C. and Barua M. K. (2016). A fuzzy-based multi criteria decision making approach for supply chain risk assessment in Indian pharmaceutical industry. *International Journal of Logistics Systems and Management*, Vol.25 (2), pp.245-265.

Yandamuri S. R., Srinivasan K., Bhallamudi, S. (2006). Multi objective Optimal Waste Load Allocation Models for Rivers Using Non-Dominated Sorting Genetic Algorithm-II. *Journal of Water Resources Planning and Management*, Vol.132 (3), pp.133-143.

Yu X., Li C., Shi Y. and Yu M. (2010). Pharmaceutical supply chain in China: Current issues and implications for health system reform. *Health Policy*, Vol.97 (1), pp.8-15.

Zhao Z. Y., Zhao X.-J., Davidson K. and Zuo J. (2012). A corporate social responsibility indicator system for construction enterprises. *Journal of Cleaner Production*, Vol.29, pp.277-289.