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Presenting a Stable Planning Model for Designing Networks of Sustainable Supply Chain the Steel Supply Chain According to Supplier's Disorders

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Abstract: *Nowadays, the environmental, social, and cultural concerns led to the matter that researchers and scholarly search in order to develop and provide new approaches in supply chains to involve the sustainable development of the supply chain. Furthermore, current supply chains are exposed to a wide spectrum of the risks that these risks can danger the performance of suppliers and the entire supply chain. This article design the reliable supply chain network with considering economic, social, and environmental dimensions under the uncertainty conditions and the disturbances of suppliers. The proposed model has three objectives minimize the total supply chain network design, minimize the environmental effect of the supply chain, and maximize social responsibility in the supply chain. To fix the programming model three proposed objective function Merge function TH is used. Finally, the proposed mathematical programming model is implemented in Iranian steel supply chain and the performance of proposed model has been reviewed and approved.*

Keywords: *The Steel Supply Chain, Designing Networks of Sustainable Supply Chain, Environmental Effects, Social Effects, Disorders, Merge Function TH, Robust Optimization*

INTRODUCTION

Supply chain network is facilities include suppliers, construction units, assembly and distribution centers that flow in order to meet customer demand, materials and information within or between them. The supply chain not only covers the production and supply activities, but also includes the activities of transportation, warehousing and retail sales as well. Decision making in the field of supply chain management like any other decision-making process, take place according to alternation and the frequency of taking that decision and also the impact of its time horizon, at three levels: strategic (long-term), Tactical (medium-term)And operational (short-term).

Recently, many studies are done in the field of supply chain network design, but less attention has been paid to the environmental issues in designing a supply chain network. In one study Pishvaee et al. (2011) have paid to loop supply chain network design depending on circumstances uncertainty demand, transportation cost and the rate of return. In another study, with using this optimization approach paid to design the perishable goods supply chain network in an agile environment (Hasani et al., 2012). In this study demand and the cost of purchasing were considered as indecisive parameters. In the end, the necessity of using Robust Optimization Model, In contrast, deterministic model by using Numerical experiments was shown. Vahdani et al. (2012a) by using a combination of the robust optimization, theory, and fuzzy multi-objective planning design direct-reverse logistics network in the industry. In this study, demand, the cost of transportation, construction costs, and facility capacity are considered as indecisive parameters. In another study, Tabrizi and Razmi (2013) use this optimization approach based on a model to design a multi-product, multi-source and multi capacities distribution network.

In another recent study, Baghalian et al (2013) provided a Multi-product supply chain network design model with regard to the uncertainty demand. The authors used stochastic programming for modeling demand uncertainty.

A proper number of multi-objective linear programming model to design a ring network multi-session closed supply chain under the uncertainty conditions are provided. The authors by using planning based credit facilities and contingency planning designed direct and reverse supply chain network with considering the environmental and social considerations (Pishvaee et al., 2012a, c). Salehi Sadeghiani (2015) designs the supply chain network with regard to operational risk and disorders risk. The proposed model by the authors is a contingency planning model based on the scenario. In yet another of the research conducted a two-phase Fuzzy model is provided to the problem of Supply Chain Network Design. The provided model causes to increase the elasticity of the network (Kristianto et al., 2014). Other research that used contingency planning for Designing of networks, can note to (Vahdani et al., 2012b; Vahdani et al., 2013a, b).

On most locating issues and supply chain network design, it is supposed that manufacture or distribution facilities and ... should be always healthy and available. But when they are impaired, the model structure or the overall network change and current developed models cannot respond this condition. So, these models must be designed in a way that it is effective even in terms of occurrence disorder (Peng et al., 2011). Another study that considered the risks of disorder in the issue of inventory of the integrated locating is presented by Aryanezhad et al. (2010). In this study, it is assumed that Distribution centers experience Random disturbance. In two studies which are done recently, (Azad et al., 2013, 2014) paid to direct logistics network design in which the facilities and modes of transportation experience Random disturbance. In this research, reliability strategies are used to deal with Random disturbance. Murray et al (2014) examined sustainable supply chain network design issue in terms of the disorder risk. The authors in addition to the concentrate on the risk of the disturbances have a special emphasis on the environmental dimension of the supply chain. Azad and colleagues (2014 provided a supply chain network design model to mitigate the effects of disturbances effects in the distribution center.

In the other studies, closed-loop supply chain network is designed in the terms disturbances in production and distribution centers in the absence of uncertainty (Hatefi et al., 2014 a, b; Hatefi and Jolai, 2015; Torabi et al., 2015). The evolution of design literature of the Network shows that integrated design of the direct supply chain networks in recent years has attracted the attention of many researchers. In addition to this matter that in recent years Models have been developed in this area, but providing the advanced and more realistic models that consider uncertainty parameters and random disturbance of the suppliers simultaneously is felt. Furthermore, given the importance of environmental and social issues the supply chain network design is felt in terms of sustainable development. In the following, is referred to the way of organizing articles. In section 2, is paid to the way of social impact assessment in the supply chain. In part 3, is presented the considered issue. Also, the proposed mathematical model problem and stable suggested model are presented in this section. The proposed solution is presented in section 4. In section 4, suggested solution method is presented. In section 5, the steel supply chain and data will be presented. The results of solving the model are provided in section 6 and in the last part conclusions will be discussed.

Social Impact Assessment

The evaluation method of the social era is developed with the purpose of assessing the social impact product and based on the concept of Lifetime. The word product contains the product and service. One of the major differences of the evaluation method of product social Lifetime with the other methods listed is productoriented of this method (Benoit, ET at. 2010). The evaluation method of the social Lifetime which is established based on thinking (lifetime), in fact, is the complementary assessment of the Lifetime environment. For this reason, the scope of this method unlike many evaluation methods of the social effects is set in a way that does do not include the area of the environment. The evaluation method of the social Lifetime which is established based on thinking (lifetime), in fact, is the complementary assessment of the Lifetime environment. For this reason, the scope of this method unlike many evaluation methods of the social effects is set in a way that does do not include the area of the environment.

Social aspects of sustainability in the resistance literature as well as literature sustainable supply chain have been less attention and hence the related literature has a serious vacuum (White and Lee, 2009). So, the extraction of social indicators is difficult and challenging. In this study, to develop social indicators the following principles are taken into consideration.

- Indicators should be chosen so that have a direct and obvious relationship with the issue decisions and mechanism of decision effect on the category of social lifetime.
- As much as possible the indicators should be selected in a way that doesn't need to use of judgmental and mental data and become based on objective and quantitative data.
- The indicators should display the difference between the social effects potential options for decisions issue properly and clearly.
- Selected indicators should have the solid background in the resistance literature or social accountability.

The social impact assessment has a key step which includes:

In the first step, first, the range and the purpose of the evaluation of the social effects should be determined. The range and the performance of the evaluation system are in accordance with the same scope and function that was mentioned in the environmental impact assessment. The purpose of the social impact assessment is both estimation of the social effects of the various options and configurations of the supply chain network.

In the second step, the life cycle stages should be determined.

In the third step, decisions associated with each stage should be determined.

Actually, for the rejection of this step, the decisions that will be adopted in the network design problem should be determined by the classification of the lifetime stages separately. The related decisions with every step of the lifetime will be the basis for evaluation the impact on the categories of social work and determine the measuring indicators. Relevant decisions can be decisions about the construction of the facility, determining the facility capacity, and the flow of goods between facilities (White and Lee, 2009). The fourth step that is the most important implementation steps is the social evaluation method of the supply chain that allocated to the determination of the categories of an impact that is affected by the decisions of the issue and also determining the mechanism of this effect (Erol et al., 2011). In this study, the social effects of the supply chain through (1) the risk of working in the offices, (2) the risk of use of the product for the consumer, (3) creation of job opportunities in effect of the establishment of production facilities is reflected in one of the functions in the objective.

Mathematical Programming Model Problem:

In this article a supply chain is considered with three levels including suppliers, manufacturers and customers. The surveyed problem includes decisions related to supplier selection of steady and unsteady, and determining the production levels, the allocation of customers to manufacturers and determining the amount of transportation freight of the each node belonging to a level to the node of the other in the supply chain stretching. The primary substance is required by Bulk producers so that each of them needs non-ferrous metal and specifies the required ratio of fusion and iron by every manufacturer, Dogs combination of iron supplied by mines with a certain ratio, is achieved. The mines, as well as iron ore with the fusion, provide clear that is possible singly is not usable by any manufacturer. Steel supply chain network studied are shown in the following figure.

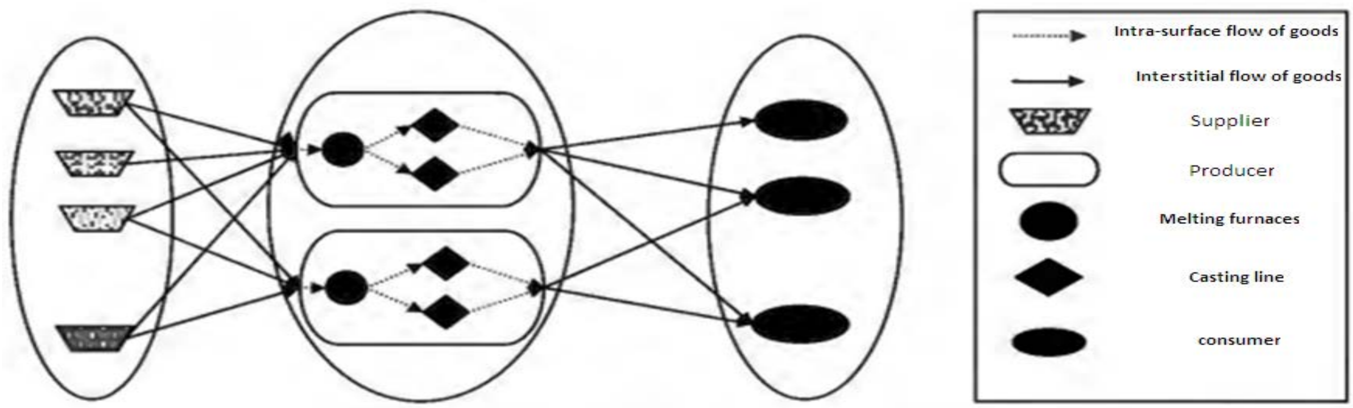

Figure 1: A three levels supply chain, including suppliers, manufacturers and customers

The production system in manufacturers is the flexible flow shops that in its first stage the number of melting furnaces is parallel in its second stage the number of products of casting line is parallel. In order to build resilience in the production of various products and production facilities of the wide range of products, crude steel production process usually designed in a way that the total capacity of the furnace become more than casting lines.

The planning horizon is one course and each of the demand of the consumers always associated with the uncertainties. Each customer demand can be determined as the interval. The chain customer demand, supply capacity of suppliers, production capacity, and the capacity of Foundry products are considered as the chain uncertain parameters. In order to assurance the minimum rate of profitability of each manufacturer, the minimum acceptable ratio of the production of manufacturing capacity (coefficient of utilization) is considered for each of them. The planning horizon is limited to the long-term phase and the medium-term, although the possibility of changing configuration network to the operational planning horizon are also available. In this chain, suppliers of iron ore are considered in two ways of reliable and unreliable and manufacturers can buy their required amount of iron ore from the reliable or unreliable from suppliers. Disturbances are effective on unreliable suppliers, while reliable suppliers are resistant against the disturbances and disturbances have no effect on them. In the other words, in the case of random disturbance suppliers must supply the orders of the manufacturers. It is clear that the cost of buying from reliable suppliers is more than the cost of buying from unreliable suppliers because the reliable suppliers are required to meet both normal conditions and disruptions in manufacturers the orders due to the capacity. But in terms of the disruption may unreliable supplier capacity decrease and cannot meet the demand of the manufacturers. In this study, it is assumed that unreliable suppliers lose the percent of their supply capacity in the impact of details disturbance and can service the rest of their capacity to the manufacturers. In this case, for each unreliable suppliers breakage supply capacity is defined, that is the amount of capacity that disappear in the effect disturbance. The mark shows the percentage of the failure of an unreliable supplier capacity. To develop mathematical programming model signs and symbols of the following are used.

Collections	
Suppliers (iron ore)	I
Manufacturers	J
consumers	K
Type of Products	P

Parameters	
▪ The cost of transportation of a ton of iron ore from the mine (I) the manufacturer J	c_{ij}^{1}
▪ The transportation cost one unit product p from manufacturer (j) to the consumer k	c_{jkp}^{2}
▪ The cost of buying a ton of iron ore from reliable mine (i) to the manufacturer J	PR_i
▪ The cost of buying Aton of iron ore unreliable mine (i) to the manufacturer J	PU_i
▪ The construction costs of one center Manufactured in location j	FX_j
▪ The cost of production the product one unit by manufacturer (j)	pc_{jp}
▪ Total cost of imports of one product unit p to consumer to (k)	Tc_{kp}
▪ The net income derived from exports of product unit p by manufacturer (j)	GI_{jp}
▪ The consumer demand k for product p	$\tilde{D}_{kp}$
▪ The maximum capacity of melting by the manufacturer (j)	$c\tilde{p}_j$
▪ The maximum production capacity p by manufacturer (j)	$c\tilde{r}_{jp}$
▪ The maximum capacity of iron ore supply by mine i	$c\tilde{m}_i$
▪ Breakage mining capacity of unreliable i(unreliable suppliers i)	pd_i
▪ The minimum acceptable ratio of the melting production smelting of manufacturing capacity (Coefficient of utilization) in the manufacturer j	pr_j
▪ Coefficient convert iron ore supplier i to a single product	per_i
▪ The maximum acceptable level of imports to total production	$\bar{I}$
▪ The minimum acceptable ratio of exports to total production	$\underline{E}$

Parameters related to environmental and social impacts	
▪ The environmental impact of transportation of one single iron ore mine (i) to manufacturer j	et_{ij}
▪ The environmental impact of producing a unit of output product p in the manufacturing j	ep_{jp}
▪ The environmental impact of transportation One product unit p from the manufacturer J The consumer k	ec_{jkp}
▪ The average per capita number of days that employees manufacturing center j lose in the accident	ms_j
▪ The vacancy rate for setting up a manufacturing center is created in the j places	JO_j
▪ Percent of non-compliance and crop damage product p in the center of manufacturing j	ps_{jp}
▪ The maximum amount that the social impact related to safety	IP^{mac}
▪ And health personnel production centers will be give	$IP^{\min}$
▪ At least some of that social effects related to the safety and health personnel production centers can be gave	IM^{mac}
▪ The maximum amount that the social impact related to safety and customer satisfaction (consumers) can take	$IM^{\min}$
▪ At least some of the social impact related to safety and customer satisfaction (consumers) can take	$JO^{\max}$
▪ The maximum amount that the social impact of job opportunities in the manufacturing centers can take	$JO^{\max}$
▪ The maximum amount that the social impact of job opportunities in the manufacturing centers can take	$JO^{\min}$
▪ Significance (relative weight) social effects related to the safety and health personnel production centers	W_1
▪ Significance (relative weight) social impact related to safety and customer satisfaction (consumer)	W_2
▪ Significance (relative weight) social impact of the jobs created in manufacturing	W_3

Decision variable	
If the i mines considered reliable in the supply chain, Otherwise	$AR_{ij} = \begin{cases} 1 \\ 0 \end{cases}$
If the ii mines considered reliable in the supply chain Otherwise	$AU_{ij} = \begin{cases} 1 \\ 0 \end{cases}$
If in place j constructed a manufacturing center otherwise	$Q_j = \begin{cases} 1 \\ 0 \end{cases}$
Amount of purchase of iron ore from reliable mines (i) to manufacturer j	XR_{ij}
Amount of purchase of iron ore from reliable mine (i) to manufacturer j	XU_{ij}
Amount of products production p by the manufacturer j	V_{jp}
Amount product transportation p from the manufacturer j to the consumer k	W_{jkp}
Amount of the product imports p by the consumer k	Y_{kp}
Amount of the product exports p by the consumer j	X_{jp}

According to the symbols and defined symptoms, mathematical programming model for designing suggested stable supply chain network define as below.

$$Min\,Z_1 = \sum_j FX_j Q_j + \sum_i \sum_j (c^1_{ij} + PU_i) XU_{ij} + \sum_i \sum_j (c^1_{ij} + PR_i) XR_{ij} + \sum_j \sum_p pc_{jp} V_{jp} - \sum_j \sum_p GI_{jp} X_{jp} + \sum_k \sum_p Tc_{kp} Y_{kp} + \sum_j \sum_k \sum_p c^2_{jkp} W_{jkp} \quad (1)$$

$$Min\,Z_2 = \sum_i \sum_j et_{ij} (XU_{ij} + XR_{ij}) + \sum_j \sum_p ep_{jp} V_{jp} + \sum_j \sum_k \sum_p ec_{jkp} W_{jkp} \quad (2)$$

$$Max\,Z_3 = W_1 \frac{IP^{\max} - \sum_j ms_j Q_j}{IP^{\max} - IP^{\min}} + W_2 \frac{IM^{\max} - \sum_j \sum_p ps_{jp} V_{jp}}{IM^{\max} - IM^{\min}} + W_2 \frac{\sum_j \sum_p JO_j Q_j - JO^{\min}}{JO^{\max} - JO^{\min}} \quad (3)$$

$$AR_i + AU_i = 1 \qquad \forall i \quad (4)$$

$$\sum_j W_{jkp} + Y_{kp} \ge \tilde{D}_{kp} \qquad \forall k, p \quad (5)$$

$$\sum_i \frac{XU_{ij}}{per_i} + \sum_i \frac{XR_{ij}}{per_i} \ge \sum_p V_{jp} \qquad \forall j \quad (6)$$

$$\sum_j XU_{ij} \le (1 - pd_i) c\tilde{m}_i AU_i \qquad \forall i \quad (7)$$

$$\sum_{j} XR_{ij} \leq c\tilde{m}_i AR_i \qquad \forall i \tag{8}$$

$$\sum_{p} V_{jp} \geq pr_j c\tilde{p}_j Q_j \qquad \forall j \tag{9}$$

$$\sum_{p} V_{jp} \leq c\tilde{p}_j Q_j \qquad \forall j \tag{10}$$

$$V_{jp} \leq c\tilde{r}_{jp} Q_j \qquad \forall j, p \tag{11}$$

$$V_{jp} = X_{jp} + \sum_{k} W_{jkp} \qquad \forall j, p \tag{12}$$

$$\sum_{k}\sum_{p} Y_{kp} \leq \bar{I} \sum_{j}\sum_{p} V_{jp} \tag{13}$$

$$\sum_{k}\sum_{p} Y_{kp} \leq \underline{E} \sum_{j}\sum_{p} V_{jp} \tag{14}$$

$$AR_i, AU_i \in \{0,1\} \qquad \forall i \tag{15}$$

$$XU_{ij}, XR_{ij}, V_{jp}, X_{jp}, Y_{kp}, W_{jkp} \geq 0 \qquad \forall i, j, p, k \tag{16}$$

The objective function (1) minimizes the total cost of the entire supply chain network. The first term in the objective function shows the cost of manufacturing. The second term in the objective function (1) shows the cost of purchasing iron ore from unreliable suppliers and the cost of transporting iron ore from the suppliers to production centers. The third term in the objective function (1) shows the cost of buying iron ore from suppliers of reliable and cost iron ore from the suppliers to production centers. The fourth term in the objective function (1) shows the total production costs in the production centers. The fifth and sixth show export revenues respectively with negative coefficients and the cost of imports. The last term in the objective function (1) shows the cost of transportation of goods from manufacturers to consumers.

The objective function (2) minimizes the environmental impact of its steel supply chain network. For this purpose, environmental life cycle assessment method is used. Full details of the environmental life cycle assessment methodology in section (3-6) are provided (3-6). The first term in the objective function (2) shows the total environmental effect of the transportation iron ore from suppliers to manufacturers. The first term (2) in the objective function (2) shows the total environmental impact of casting and production and the third term in the objective function (2) shows the total environmental effect of transporting products from producers to consumers.

The objective function (3) minimize the weighted average normal social effects related to the health and safety of personnel manufacturer, safety, and consumer satisfaction and the creation of job opportunities in the centers of production. Generally, measuring of corporate social responsibility (CSR) is difficult because of the broad scope and the complex nature of social issues. So, in this thesis, the most relevant social effects supply chain network design issues have been considered. Since the social effects related to the health and safety of personnel manufacturer, safety and consumer satisfaction and the creation of job opportunities in the production centers have a different scale, each of these effects has been normalized and normalized weighted sum of the social effects have been considered in the third objective function. Phrase $\sum_{j} ms_j Q_j$, shows the raw

amount of social effects safety and health of employees in production centers. Phrase $\sum_j \sum_p ps_{jp} V_{jp}$, shows the raw value of social effects related to safety and customer satisfaction and consumer products and the phrase $\sum_j \sum_p JO_j Q_j$, shows the raw value of social effects related to job opportunities created in production centers.
Limitation (4) shows that a supplier in the studied network is considered reliable or unreliable. This limitation is considered for modeling of random disturbance in supplying of the suppliers. Limitation (5) ensures that the customer's demand meet fully. Limitation (6) ensures that Fusion of raw materials purchased by each of the manufacturers in accordance with the requirements of demand. Limitation (7) shows supply capacity of unreliable suppliers. According to this limitation, the capacity of unreliable suppliers that has failure according to the percentage of failures will decrease equal to pd_i. Restriction (8) shows the capacity of reliable suppliers. Limitation (9) ensures the minimum acceptable ratio of output to melt production capacity for each of the manufacturers. In other words, this limitation shows guarantee of a minimum rate of utilization of production capacity in each of the chain manufacturers. Limitation (10) and (11) respectively apply the maximum capacity of the melting and casting lines for each of the manufacturers. Limitation (12) shows balance making of the flow of any product in the manufacturer. limitation (13) provides the policy of imports that total amount of imports in each period should be less than a certain percentage of the total production. Limitation (14) enforce export policy, which total exports should be more than a certain percentage of the total production. Finally, limitation (15) and (16) shows Binary decision variables and decision variables and flows and non-negativity of the decision.

Since in the examined network chain in this study, parameters related to Customer demand and the capacity of suppliers and manufacturers constantly associated with the uncertainty, to develop a proposal reliable twin issue, consumer demand $(\tilde{D}_{kp})$, supply capacity of suppliers $c\tilde{m}_i$ production capacity $c\tilde{p}_j$ and casting capacity centers of production $c\tilde{r}_{jp}$, have considered uncertain issue that can set some uncertainty adopt the appropriate box. According to Robust optimization approach presented by Ben-Tal et al., (2009), limitations which have parameters of uncertainty, should be written in the reliable twin form. So reliable twin equivalent restrictions (5) and (11-7) respectively written as follows. More details about reliable optimization method are presented in (Ben-Tal et al., 2009).

$$\sum_j XU_{ij} \le (1 - pd_i)(c\bar{m}_i - \rho_{cm} G_i^{cm}) AU_i \qquad \forall i \tag{17}$$

$$\sum_j XR_{ij} \le (c\bar{m}_i - \rho_{cm} G_i^{cm}) AR_i \qquad \forall i \tag{18}$$

$$\sum_p V_{jp} \ge pr_j (c\bar{p}_j + \rho_{cp} G_j^{cp}) Q_j \qquad \forall j \tag{19}$$

$$\sum_p V_{jp} \le (c\bar{p}_j - \rho_{cp} G_j^{cp}) Q_j \qquad \forall j \tag{20}$$

$$V_{jp} \le (c\bar{r}_{jp} - \rho_{cr} G_{jp}^{cr}) Q_j \qquad \forall j, p \tag{21}$$

In this model, $\overline{*}$ respectively nominal value, level of uncertainty, and scale of uncertainty are G^* and ρ_* regarding uncertain parameters models.

Method of Solving

In related literature different ways for solving Multi-objective planning issues are used. Among these methods, Fuzzy approaches have been used in a lot of research. One of the first phases, for solving multi-objective optimization is Min-max method that is presented by Zimmermann (1978). But this method in some cases produces inefficient results (Lai and Hwang, 1993). To solve the problem Min-max method an interactive fuzzy approach is presented by Sakawa et al., (1987). In addition to this approach, Lai and Hwang (1993) Reinforced method of Min-maxHas offered. Also, Torabi and Hassini (2008) A single-step approach Based on fuzzy concepts for solving linear multi-objective optimization problem has been known in the related literature as TH. The authors of in the research have proven the effectiveness of its methods. According to another study, Vahdani et al (2012) offered a hybrid approach based on Robust Optimization and TH for solving optimization issue multi-purpose in the case that model parameter has uncertainty. In this essay, this hybrid approach for solving the problem two desired objective are used. Implementation steps of the hybrid approach are as follows:

The first step: In this step, all the uncertain parameters and distribution functions regarding each of them are identified.

The second step: In this step, the considered uncertain issue is provided, or with regarding uncertain parameters the issue of reliable twin is written.

The third step: In this step, positive ideal solution (PIS) and negative ideal solution (NIS) are determined. To achieve the positive ideal solution for each of the objective functions that are shown with $\left(f_1^{PIS}, x_1^{PIS}\right)$, $\left(f_2^{PIS}, x_2^{PIS}\right)$ and $\left(f_3^{PIS}, x_3^{PIS}\right)$. It reliable twin for each function separately dissolved and optimum values is determined. So we have:

$$\left.\begin{array}{r} f_1^{PIS} = \min f_1 \\ s.t. x \in X \end{array}\right\} \Rightarrow \left(f_1^{PIS}, x_1^{PIS}\right) \tag{22}$$

$$\left.\begin{array}{r} f_2^{PIS} = \min f_2 \\ s.t. x \in X \end{array}\right\} \Rightarrow \left(f_2^{PIS}, x_2^{PIS}\right) \tag{23}$$

$$\left.\begin{array}{r} f_3^{PIS} = \max f_3 \\ s.t. x \in X \end{array}\right\} \Rightarrow \left(f_3^{PIS}, x_3^{PIS}\right) \tag{24}$$

Then, to get the negative ideal solution for objective functions we use the following formula.

$$f_1^{NIS} = \max\left(f_1(x_2^{PIS}), f_1(x_3^{PIS})\right) \tag{25}$$

$$f_2^{NIS} = \max\left(f_2(x_1^{PIS}), f_2(x_3^{PIS})\right) \tag{26}$$

$$f_3^{NIS} = \min\left(f_3(x_1^{PIS}), f_3(x_2^{PIS})\right) \tag{27}$$

Fourth step: In this step, a linear membership function for each of the objective functions is obtained based on the following formula:

$$\mu_1(x)=\begin{cases}1 & if\ f_1 < f_1^{PIS}\\ \dfrac{f_1^{NIS}-f}{f_1^{NIS}-f_1^{PIS}} & if\ f_1^{PIS}\le f_1 \le f_1^{NIS}\\ 0 & if\ f_1 > f_1^{NIS}\end{cases} \tag{28}$$

$$\mu_2(x)=\begin{cases}1 & if\ f_2 < f_2^{PIS}\\ \dfrac{f_2^{NIS}-f_2}{f_2^{NIS}-f_2^{PIS}} & if\ f_2^{PIS}\le f_2 \le f_2^{NIS}\\ 0 & if\ f_2 > f_2^{NIS}\end{cases} \tag{29}$$

$$\mu_3(x)=\begin{cases}1 & if\ f_3 > f_3^{PIS}\\ \dfrac{f_3-f_3^{NIS}}{f_3^{PIS}-f_3^{NIS}} & if\ f_3^{NIS}\le f_3 \le f_3^{PIS}\\ 0 & if\ f_3 < f_3^{NIS}\end{cases} \tag{30}$$

Actually, shows the degree of satisfying the objective function h.

The fifth step: in this step, It offers through the integration of TH reliable twin The a mathematical programming model becomes single-minded. It should be noted that TH method ensures that the results obtained are efficient. TH merge function is accessible through the following relations:

$$\begin{aligned} & Max\,\lambda(x)=\psi\lambda_0+(1-\psi)\sum_{h=1}^{3}\phi_h\mu_h(x)\\ & s.t.\\ & \quad \lambda_0\le\mu_h(x),\ h=1,2,3\\ & \quad x\in F(x),\lambda_0\ and\ \lambda\in[0,1] \end{aligned} \tag{31}$$

In the above model $F(x)$, justified district related to the issue suggested restrictions of reliable twin is shown. Also ϕ_h and ψ are shown respectively, the importance of the objective function Hth and coefficient of compensation. Relation $\sum_{h=1}^{3}\phi_h=1,\phi_h>0$ is established at all the time. Furthermore, the optimal value of decision variables, the lowest degree of satisfaction indicates the objective functions. Merge function TH constantly looking for a compromise deal Min between the operator and the operator is based on the sum of ψ.

The sixth step: in this step, amounts of the uncertainty, the coefficient of compensatio and the relative importance of fuzzy goals is determined and single-minded supermodel is solved. If according to the values of these parameters, obtained answers for decision-makers was acceptable the algorithm stops otherwise by changing these parameters other answers search should be studied.

The steel supply chain data

In this section, the implementation of the proposed model in the steel supply chain Iran will discuss. Mines in this chain Chador Malu, Golgohar and Choghart, domestic suppliers and mines, six suppliers Smark, KUDERMUKH, CARAJASE, CVRD, FERTECO and MBR as foreign suppliers are considered. In this chain, Khuzestan Steel Company (KSC), Mobarakeh Steel Company (MSC) and Esfahan Steel Company (ESC) recent production chain (1) Mobarakeh Steel Company, (2) ESCO,(3) Mixing steel,(4) Iran National Steel Industrial Group, (5) Ahwaz rolls, (6) Khuzestan Steel auxin, (7) steel Azerbaijan,(8) Khorasan Steel,(9) steel Caspian Kabir (10) Iran Alloy Steel consumers supply chain, are considered. Each manufacturer for producing iron ore needs the ratio of specific fusion. Current commodity is in the first category chain, iron ore in the second, three products Bildt, Blooms, and slabs of different dimensions. So the reviewed supply chain is three products supply chain. Conversion ratio each type of iron ore product depends on the proportion of its fusion and should is less than 1.66 tons of iron ore is required. If the product import policy adopted In every valley shall not be more than 5% total demand in that period and also it is export policy the total export at least 10% total is the total production chain. The purchase value of per ton of ore from an unreliable supplier is considered 456 thousand dollars and if the supplier is reliable, this value can expand to double. The cost of transporting a ton of product is considered about a mile from the 58 USD. For calculations of the cost of transport between the two centers, by multiplying shipping product units for distance (km) in the distance between the two centers are used. Khuzestan steel production capacity of centers, Mobarakeh Steel, and Esfahan Steel Company is considered respectively 250, 700, and 800 thousand tons. The maximum capacity of slabs, Bloom, and Billet in Khuzestan Steel respectively 100, 150 and 200 thousand tons is intended. These values for Mobarakeh Steel are considered respectively 230, 200 and 250 thousand tons and for Esfahan Steel Company are considered respectively 12, 80 and 100 thousand tons. The cost of producing slabs, bloom and Billet in manufacturing centers are considered respectively 2024, 2052 and 2064 thousand USD. The cost of imports or exports thousand tons of slabs, blooms, and billets is considered respectively 8.2833, 8.2872 and 6.2889 million RS.

Environmental effects of transportation a ton of product about a mile from 17.3 and the environmental effect of producing one kilo of product Bildt, Bloom, or slabs based on the Eco-indicator is intended to 32.2. The following table shows the values of other parameters supply chain network. The number of jobs created in case of construction steel manufacturing center, Mobarakeh Steel and Khuzestan Steel respectively led to the hiring of 15,000, 14,000 and 7,000 people. In the following table, the parameters cost in terms of dollars and parameters relating to capacity, the amount of production in thousand tons.

Table 1: the amounts of network parameters of the steel supply chain

Parameters	Random distribution function	Parameters	Random distribution function
$c\overline{m}_i$	~ Uniform (200,400)	G_{kp}^{D}	~ Uniform (5,10)
$\overline{D}_{k1}$	~ Uniform (10,50)	G_{i}^{cm}	~ Uniform (10,20)
$\overline{D}_{k2}$	~ Uniform (15,40)	G_{j}^{cp}	~ Uniform (20,30)
$\overline{D}_{k3}$	~ Uniform (10,70)	G_{jp}^{CR}	~ Uniform (5,15)
ps_{jp}	~ Uniform (0.01,0.09)	ms_{j}	~ Uniform (100,900)

The purpose of this article is designing and solving the model related to Iranian Steel Supply Chain, import and export planning goals, planning for the development of the manufacturers, estimating funds needed To develop manufacturers, supplier selection reliable and unreliable and long-term contracts required to supply iron ore domestic and foreign mines. Tactical goals can also refer to determining the tack of the amount of each type of product, the node belongs to a level, the nodes belonging to the next level, and determining levels of the production.

Results

The results of the implementation of the reliable models and certain model

To solve the issue of the reliable twin by using the combined solution in different levels of the uncertainty first should achieved the positive ideal solution and negative ideal solution for each of the objective functions at every level of uncertainty. To do this the table's payoff and relations (22) to (27) were used. For convenience, we change all levels of uncertainty equally. So, this relation $\rho_* = 0, 0.25, 0.5, 0.75, 1$ is considered. For solving the robust model the importance of the social effect is consider equal to $(W_1 = W_2 = W_3 = \frac{1}{3})$.

After obtaining the positive and negative ideal solutions at every level of uncertainty function the membership of each of the objective functions should calculated based on (28) to (30). After calculating membership functions TH provided with the function of integration in (31) can calculate the final results. The following table shows obtained results that were calculated using the software GAMS. The following table has been shown optimal values of the objective functions and the degree of membership of each of the objective functions in both uncertain and certain cases. It should be noted that When Level of uncertainty in the Twin model is considered Zero; the twin of the reliable model will change to the certain model. To obtain the following table, $\phi_1 = \phi_2 = \phi_3 = \frac{1}{3}$ $\psi = 0.5$ and $W_1 = W_2 = W_3 = \frac{1}{3}$ are used.

Table 2: the performance of twin reliable model compared to the certain model

	The certain issue		
	(f_1, μ_{f_1})	(f_2, μ_{f_2})	(f_3, μ_{f_3})
	$f_1 = 82732623.02$	$f_2 = 52900526.94$	$f_3 = 0.7729$
	$\mu_{f_1} = 0.9359$	$\mu_{f_2} = 0.996$	$\mu_{f_3} = 0.9570$
the level of uncertainly	**the twin reliable**		
	(f_1, μ_{f_1})	(f_2, μ_{f_2})	(f_3, μ_{f_3})
0.25	$f_1 = 87091430.01$	$f_2 = 56046605.50$	$f_3 = 0.7724$
	$\mu_{f_1} = 0.9525$	$\mu_{f_2} = 0.9395$	$\mu_{f_3} = 0.9954$
0. 5	$f_1 = 94695483.35$	$f_2 = 60072835.55$	$f_3 = 0.7723$
	$\mu_{f_1} = 0.9288$	$\mu_{f_2} = 0.9296$	$\mu_{f_3} = 0.7732$
0.75	$f_1 = 98328147.37$	$f_2 = 62978505.54$	$f_3 = 0.7723$
	$\mu_{f_1} = 0.9451$	$\mu_{f_2} = 0.9462$	$\mu_{f_3} = 0.9512$
1	$f_1 = 101870312.7$	$f_2 = 65792110.31$	$f_3 = 0.7714$
	$\mu_{f_1} = 0.9616$	$\mu_{f_2} = 0.9740$	$\mu_{f_3} = 0.9616$

As the results show by comparing the objective function in the case of definite and stable it can be concluded that all three objectives in the case of stability have been got worse that this represents supported models in the face of uncertainty parameters. In the other words the issue of reliable Twin that supply the supply chain network in the face of uncertainty will impose more cost (first goal) to the network compared with the certain mode. And its total environmental effects increase and its social effects compared to the certain mode have decreased. By comparing the optimal value of objective functions (total costs and environmental effects and social effects of the network) in the different level of uncertainty also it can be concluded that with increasing levels of uncertainty total costs and environmental effects supply chain network increased and the social effects of networks has declined. This means that when the reliable model supports the supply chain network against more uncertainty the total costs and environmental effects of the whole network increased and the average normalized of balanced social effects decreased.

The analysis of sensitivity of the proposed model based on parameters of the model TH

In this section, with the value of the objective function weights in the merge function TH that is presented in (45), the balance between the objective functions two by two obtained and is shown in the chart. in fact, in this section, we achieve the balance between the objective functions two by two by changing the values of the objective function weights. For this purpose first, the balance between the two objective functions, the total cost of the network, and environmental effects have been obtained. In all the calculations in this part, these amounts $\psi = 0.5,\ \rho_* = 0.25$ are used.

The following figure shows Interoperability of two objective functions, total cost, and environmental effects. To get this we should change the form of the objective function of cost and the objective function environmental effect and place the weight of the objective function of social effects to zero. For this purpose, we use $\phi_1 = 1, 0.8, 0.6, 0.4, 0.2, 0;\ \phi_3 = 0;\ \phi_2 = 1 - \phi_1 - \phi_3$. The results presented in the following figure shows that two objective functions are in conflict with each other.

This means that the movement of an objective function toward desirable (Further satisfy of the objective function) requires movement of another objective to the undesirable (less satisfying). On the other hand, the improvement of an objective function will cause deterioration of another objective. In the other words, increasing the function of the whole cost will cause to improve and increase the whole costs, the environmental effects and the environmental effects of the supply chain network will decrease and vice versa.

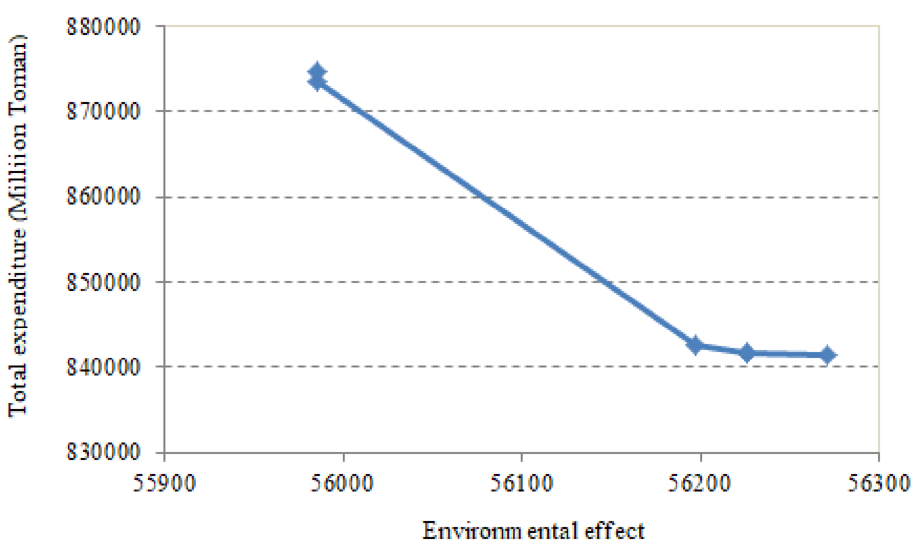

Figure 2: The interaction effect of two objective functions of environmental effects and the cost of the whole network

the following figure shows Interoperable the two objective functions environmental effects and social effects of supply chain network. The results presented in the figure below shows that two objectives are in conflict with each other. This means that the movement of an objective function toward desirable (Further satisfy of the objective function) requires movement of another objective to the undesirable(less satisfying). On the other hand, the improvement of an objective function will cause deterioration of another objective. In the other words, increasing the environmental effects will cause to improve and increase social effects, that it is not desirable for us because the reduction of the damaging effects of the environment is pleasant. So the following figure shows the contrast between the following two objective functions.

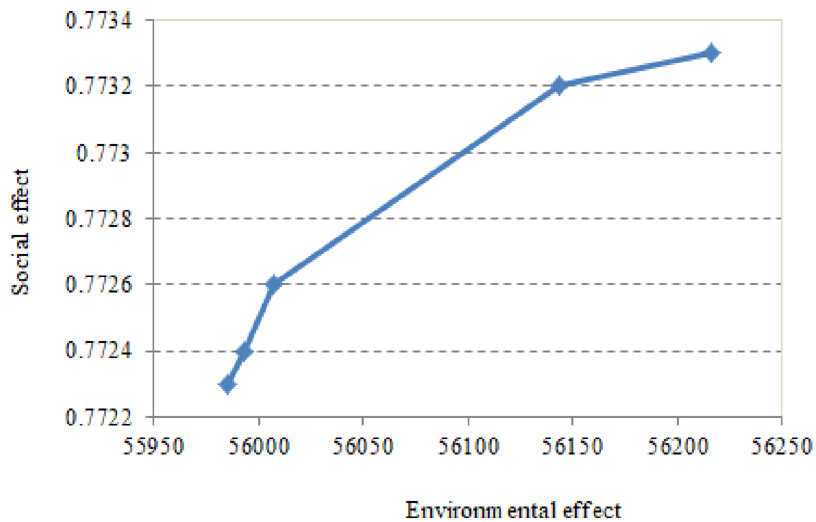

Figure 3: The interaction effect of two objective functions of environmental effects and social impacts

the following figure shows the interaction performance of two objective functions, total cost, and social impacts. Based on this figure, we can conclude that by spending more costs for sustainable supply chain network design, social effects of supply chain network have been increased.

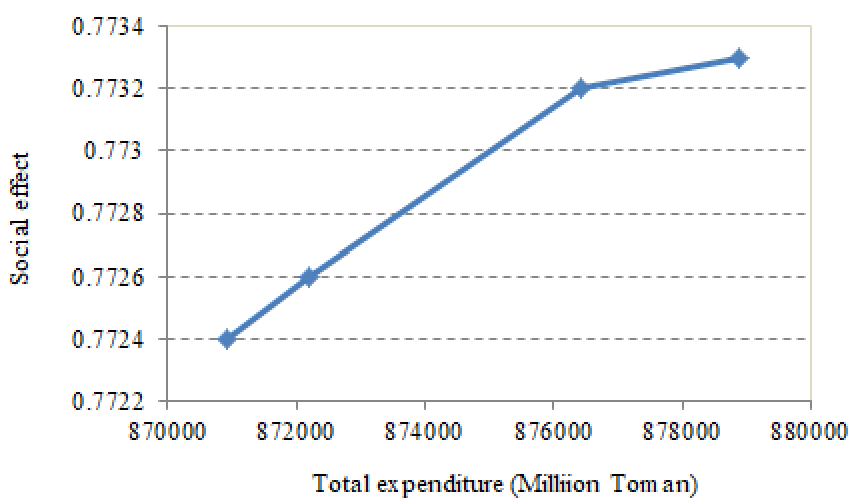

Figure 4: the interaction effect of two objective functions the total cost of Network and social impacts

Conclusion

This article paid to the supply chain network design according to aspects of sustainable development means the economic, social, and environmental dimension in conditions of uncertainty and disturbances of suppliers in the steel supply chain. The steel supply chain network is three products supply chain (including billets, blooms, and slabs) and one period which contain suppliers, manufacturing centers, and consumers. The considered uncertainty is related to consumer demand, the capacity provided suppliers, production capacity and casting capacity in the manufacturing. For modeling uncertainties, the Robust Optimization approach is used. For modeling disturbances, the strategies and the concept of reliability for relieving the effect of disturbances have been used. The analyzed subject has three functions that include the aim to minimize supply chain network design, Minimize the environmental impact of the supply chain, and maximizing social accountability or social effects of the supply chain. The environmental impact of transporting goods and the environmental impact of production the second objective function is reflected in the centers of production. In the third objective function, the problem of the weighted average normal social effects regarding manufacturer health and safety personnel, safety and consumer satisfaction and created job opportunities is reflected in the manufacturing centers. From the merge function for solving the problem three proposed objectives are used. Eventually, the proposed models are implemented in data on the steel supply chain and accordingly analysis of the results was carried out.

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