Int. J. Nonlinear Anal. Appl.
Volume 12, Special Issue, Winter and Spring 2021, 1311-1336
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/IJNAA.2021.5668

Multi-level supply chain recovery after disturbance; Mathematical modeling of Iran Khodro chain recovery

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(Communicated by Ehsan Kozegar)

Abstract

In this research, the main purpose of managing disorders that occurs in the supply chain of Iran Khodro, in such a way that the supply chain can keep the service provided to the customer in the event of a disturbance, or created the lowest changes in the customer's service. . For this purpose, first examines the concepts and theories associated with disruption and recovery in the supply chain, and then the research mathematical model is designed and presented. Finally, the validation of the model and solving a model based on data collected from Iran Khodro is presented in one of the real issues of the company. Based on the results, it is determined that the occurrence of an impairment in one of the suppliers can disturb the entire supply of supply chain members to disturb, and when the disorder is corrected, the retarded production process to the next periods. Transferred and its recovery in subsequent periods will continue with the production disturbance of subsequent periods to 15 periods, and then its impact will be resolved, which can be expressed by taking 1 year production periods that the impact of sanction and lack of production of production pieces It has been remained in the system for 15 years and can disrupt this system without increasing production capacity and will recover the production system for 15 years.

Keywords: Supply chain, Supply chain disorder, Supply chain recovery, Mathematical modeling, Metric LP technique,Algorithm NSGAII

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Received: June 2021 *Accepted:* September 2021

1. Introduction

The globalization of economics and outsourcing growth makes the supply chains more complex and more complex, and so supply networks are more vulnerable to disruptions. Because the defect in one of the chain connections can defect the entire chain [17]. With the development of globalization, the reactionary property of the supply chains has decreased. In many industries, supply chains have been exposed to large risks due to lack of support capacity, which has so far been unprecedented. Many companies focus on concepts such as pure activities, timely delivery, single source production and integrated with the goal of reducing costs and cases of this hand, which led to the reduction in resources in those industries and in the event of a disorder, the lack of resources leads to intensification. At least the time of supply of raw materials and delays in the production of the final product will be [13].

In the 1950s, many companies adopted a variety of measures to improve financial performance. These actions focused on three sections:

1. Increased income includes: More variation of production, speed increase in new products and broader sales markets;

2. Decrease costs include: Providing requirements with a decreasing approach, timely source, including markets and electronic auctions, transfer facility to other areas, JIT inventory systems and inventory management by the seller;

3. Reducing assets included: outsourcing production activities, information technology and logistics [2].

These measures will be in a stable environment, but the modern business environment is continuous with change. Recent changes in the supply chains have created a long dispersion and complexity due to globalization and increasing the number of chain partners. This reduces the direct control and supervision of companies without corporate intermediary on the current activities of the supply chain [8]. On the other hand, the long and complex supply chains usually respond slowly to changes and will have vulnerable points as well as multiple disorders [12].

The arrival of some global automakers to Iran from China and France and even Russia, according to the conditions created in the province (before Barjam, during the period and the period after the Barjam), will reduce the monopoly activity of the Iranian company, which It causes any injuries in the event of an impaired supply chain lead to irreparable costs in the market.

Also, labor strikes are a subject that may occur in many companies. Especially in Iranian companies who have high dependence on their workers and a high number of workers in these companies. Nearly 110,000 people are engaged in two Iran Khodro and Saipa companies, which is a significant number of statistics. The incidence of any disruption in the supply chain for various reasons can lead to major issues for the country.

On the other hand, the unstable state of the dollar in the Iranian currency market, which disrupts the purchase and sale of parts of domestic and foreign producers, can also insert this disruption to the supply chain and coping for the reconstruction and recovery of the company after the disruption of the necessity A lot of for the company.

In this research, the main goal of managing disorders that occurs in the supply chain of Iran Khodro companies, in such a way that the supply chain can maintain the level of service provided to the customer in the event of a disturbance, or the lowest changes to the customer. Provided. For this purpose, this continues to examine the concepts and theories associated with disorder and recovery in the supply chain, and then the mathematical model of the research has been designed and presented. Finally, the validation of the model and solving a model based on data collected from Iran car is presented in one of the real issues of the company.

2. Concepts and theories

2.1. Disruption of the supply chain

According to Fernandez et al. [4], the supply chain disorder occurs as planned, which affects the flow of materials, information and other components. Therefore, organizations should continuously identify, measure and evaluate their operating environment and continuously identify the risk associated with a potential disorder. In this case, it can be seen as effective reduction in the negative effects of disruption of the supply chain [4].

Huntington [7] believes that disruption begins with an unpredictable event and cut off the supply of supply chain. This random occurrence can include natural disasters, strike staff, dependence on a supplier, bankruptcy, war or political instability [7].

In other definition, chain disorders are not planned and unpredictable events that disrupt the supply of goods and materials of the supply chain. As a result, members of the supply chain face financial and operational risks [3]. According to Kumar et al. [9], the supply chain disorder is stopping in the normal and continuous chain flow that will be associated with multiple negative effects [9]. And finally, the religion and ingiveness define the disorder: "Anything on the flow and supply of raw materials, parts, components and goods, from the origin to the point of the final demand" [1]. Any serious and important interruption will affect the performance of the company from ways that are predictable. Interruptions have a specific exponential effect on the company's performance. The company's performance can be measured in terms of sales, production level, profit, customer service or any other appropriate criterion. Disturbance or dynamism The company can be displayed in eight steps [15].

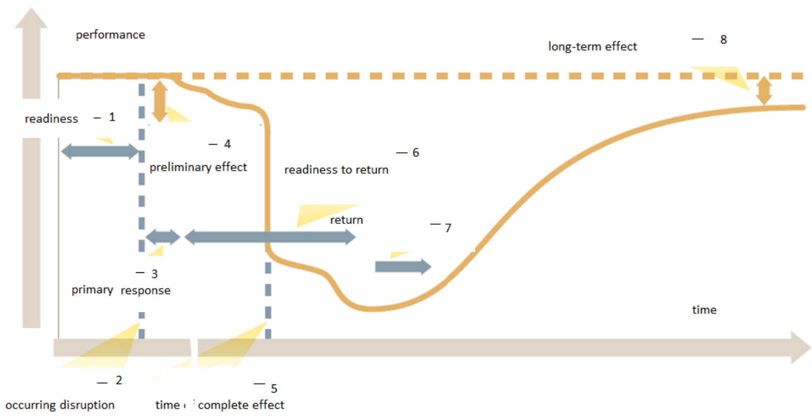

Figure 1: View of a Disorder [15]

Factors of uncertainty are usually divided into two groups of possible factors and non-probable factors. The first group can be described through probable models. To explain the lack of non-possibility of fuzzy logic with certain membership functions can be used. One of the main risks of uncertainty is the occurrence of an impairment that is influential in the planned supply chain path. The impact of the interruption of the supply chain is divided into two main categories [15]: a - The effect of targeted disorder: This category of disorders can be hostile (irregularities in supply chain activities) or non-hostility (promotion of chain performance Be funded). Examples of the effects of targeted disorder are: theft, terrorism and financial violations and... b - the impact of non-targeted disorder: the second category is natural, economic or technological. An example of the impact of non-targeted economic disorder, demand fluctuations and the whip effect.

Usually in uncertainty analysis, four aspects should be considered. The first item is uncertainty and the second risks. The third aspect of the impact of disturbance (disorder) and the last aspect of severe effects of turmoil (deviations) [5]. In the table below, examples of disorders and interruptions are listed in the supply chain.

In total, lost profits through targeted disorders (for example, terrorism and theft) and non-targeted (such as demand fluctuations) can be about 30% of the annual trading volume. The following cases show the attention of the modern supply chain to discuss the uncertainty and necessity of timely management of them as a very critical theme. Because a set of crises is happening and each of them alone can make the entire supply chain are compromised. Dynamic supply chain activities with uncertainty features in this chain (including: customer requirements, resource capacity, shipping time, production time, costs, quality, priorities and information shortages) added on its complexity. Are [15]. The inner and external incidents encounter the nature of the supply chain, the internal events of the supply chain have a more destructive effect compared to external events. The external incidents of the supply chain are called "environmental events" (including changes in technology or economic, competitors and ...). Inner incidents may be on the top supply chain (including: deliveries or receives, lack of available material or service, and ...), middle or central part of the chain (sufficient capacity and proper capacity, performance or output of the process of the process and the process ...) and the bottom side (including: changes in the composition of demand, change in scheduling or demand volume requested) [8].

Environmental events can also build suppliers in meeting the needs of the manufacturer and lead to logistical problems that will lead to delays with delay, defective or waste. An example of environmental events include storms, earthquakes, sudden changes in air, tsunami, fires, terrorist attacks, political warfare, computer viruses, etc. [8].

Disorders in the supply chain creates uncertainty that may indicate uncertainty in controlling, process, supply and demand. The attempts to create higher performance chains and lower costs may lead to unpredictable results that increase the risk of an irregularity and interruption of the supply chain or extend the severity of the events [8].

Supply chain disorders have become an important and vital issue for many companies. Functional drop due to disruption has become one of the important issues of today's business environment. Environmental changes, more complex and more vulnerable supply chains have sustained companies for disruption. According to research conducted at the University of Cranfield in 2017, factors that increase the potential impairment of the supply chains include: globalization of supply chains, specialization of production processes, increase outsourcing, reducing the number of suppliers, variability Top demand and technology innovations. Recent cases in the shortage of parts in Ericsson, due to fire in the supplier facility, shortage of pieces in Motorola, which reduced the company's ability to meet the demand for camera phones, stop several Japanese automotive factories due to the failure of the release of the only rims Piston refers to the earthquake [3].

Table 1: An example of disorders and their impact on the supply chains (Paragoli et al., 2017)

Effects	Example	Factors
Losing 13.4 million euros per year Losing 4.6 million euros per year Losing more than 15 percent of the volume of annual equations	retail manufacturing	Theft and Product failure
Five Ford Facility was Closed for a long time	eleventh of September	terrorism
Disruptions in many supply chains	Somali, 2008.	Banditry (piracy)
1. Apple PC production stopped in Asia 2. Significant reduction of Volkswagen Company 3. Stop cooperation of shipping companies and other foreign companies with Iranian companies due to avoiding heavy crimes and eating the supply chain balance and transportation	1. Earthquake in Thailand, 1999 2. Flood in Saxony Germany in 2002 3. Sanctions of Iranian companies by Trump 2018	natural disaster
Interruptions in gas supply from Russia to Europe, millions of euros damaged Gazprom Company and its customers.	Gas crisis, 2009	Political crises
Reduce or reinforce production in most supply chains	The Great Recession, 2008	Financial crises
Losing customer orders and reducing 15% annual trading volume	Demand fluctuations Internal imbalance	Coordination problems

In the studies of Kumar et al. [9], the supply chain disorder is divided into three main groups:
A: Supply-side disorder: Construction, delivery and amount of inventory
availability in time and location;

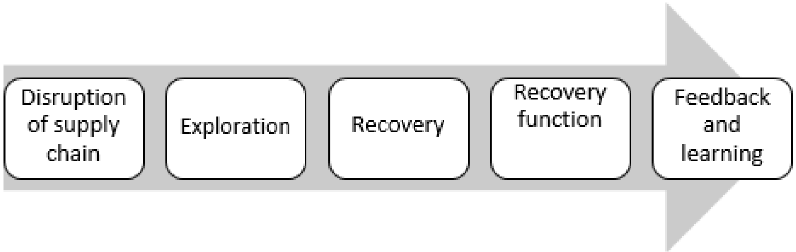

Figure 2: Steps of Disorder Management [3]

B: Production Disorders: The process of making products or services by Central Company;

C: Demand Disorders: Includes distribution and sales of products to customers (Kumar et al., [9]).

Cao et al. [3] provides a model for post-occurrence management, which includes exploration and recovery and recovery process. After the recovery step, the overall performance assessment is carried out and eventually happened, lessons for not repeating similar events in the future [3].

2.2. Internal and foreign applied research

Part and colleagues in their research provided a fuzzy-probable design model for designing the chain network footstep. This research provides a new fuzzy-probabilistic model for designing a multi-time supply chain network, which simultaneously addresses these two important issues.

First, in order to design the model, taking into account two vulnerable and vulnerable types of impact on the occurrence of potential disorders, a Pessimistic approach was used and then developed a fuzzy model for exposure to business uncertainty.

The flexibility in the customer limit (s) and determining the level of this restriction (s) has also been studied in the model. In addition, in order to develop the concept of reliability in this issue and covering important characteristics of real world issues, partial impairment and customer expected time limit in modeling. Finally, in order to display the effectiveness and application of the developed model, a case study was used for an active company in the Iranian health system [13].

Rabbani et al. In the research of multi-objective design of the supply chain, considering the risk of facilities, supply and demand in the non-determination conditions of economic parameters. In this paper, the issue of the design of the supply chain network is modeled as a mathematical planning of fuzzy mixed multiplicity, whose goals are the current value of the current income, delayed product receipt by customer, as well as reliability of suppliers by considering risk Demand, supply and disorder are used to use an interactive role planning approach to solving the multiplied math model. To ensure the high level of supply chain performance, if an incident, the index is used by using scenarios based modeling approach. Also, due to lack of information, some economic parameters such as tax rate and inflation rate are considered fuzzy. Due to the complexity of the model, the genetic algorithm has been used to solve large dimensions. In the end, the performance of the model and the proposed method are examined in the form of numerical examples [14].

Lohe et al. [11] In the research, a comprehensive fuzzy assessment of the disruption and threats in the supply chain with the transportation approach to the transportation network. In this research, they examine the components of the supply chain network and the likelihood of occurrence in each section of this chain. The data used in the research were collected from activists in the supply chain. Using interviews with each of these activists, the dangers and threats that cause disruption to the supply chain were identified. Then the required data were collected using a set of vocabulary that showed possible ambiguity and fuzzy. Finally, the fuzzy mathematical model was designed to reduce the impact of these disorders. The results showed that the events created for transportation terminals, lack of facilities and equipment and disruption of information networks have the greatest impact on increasing disruption in the supply chain [11].

Kamal Ahmadi and Mellat Parast [8] in a research assessment strategy for reducing the effects of impact in the supply chain. In this paper, they designed three scenarios to reduce the impact of dysfunction in the supply chain, which include unpredictable inventories (inventory of surplus assurance on system requirements), spare suppliers (suppliers that the system currently does not supply materials But they are identified in the system to refer to them if needed) and the third scenario are also supported suppliers that continue to interact with them under any circumstances and has special relationships with them. The results of the research show that all three scenarios reduce risk and costs compared to the general model of supply chain, but the choice of backup suppliers in the supply chain more than other scenarios can be effective [8].

Sawik states that one of the methods for preventing excessive reduction in inventory storage and achieving the optimal inventory is that the expected cost of inventory in the total cost equation is included and gathered with other costs. But predicting future states and estimating various costs requires spending significant resources for collecting relevant data, which makes it difficult to implement [15].

3. Research methodology

Philosophically, the present research is proven, and in the researcher, by providing a double-objective mathematical model, seeks to solve the dilemma of supply chain recovery after a disturbance of the supply chain in Iran Khodro. The type of research is applied in terms of purpose, and since seeking to provide a mathematical planning model for managing disorders in the multilevel supply chain. Also, for more application, the model and the possibility of evaluating the effectiveness of the model and the solution method, a real supply chain in the automotive industry of Iran (Iran Khodro company) has been studied, which is a case study from the perspective of data collection. It is also a quantitative study and provides a mathematical model and solving it to reduce the impact of disorders in the supply chain.

3.1. Mathematical design

In order to design the mathematical model in the present study, the variables and parameters of the model have been identified and then the two objective function of the research has been presented. This function is based on relationships that have been explained due to the limitations of the researcher in providing the entire model, and only the final model used in the research has been presented.

3.1.1. Variables and model parameters

In the following table, the parameters and variables of the model are introduced:

Table 2: Parameters and model variables

Symbol	Model parameters	Symbol	Model parameters
TS_d	The period of impairment in the supplier	s:1, 2...S	Viewers related to suppliers
T_d	The period of disorder in the manufacturer	r :1, 2...R	Viewers related to retailers
Q_{dr}	The amount of product destroyed in Retail Dysfunction r	A_s	Setup cost of s
q_s	The amount produced in the S before the occurrence of disorder	AS	The cost of launch producers
q	The amount produced in the manufacturer before the occurrence of disorder	AO_s	Registered cost of ordering from s
ρ	The time of production activity in the provider under normal conditions	A_r	Registered cost of retail ordering r
ς	Production unemployment time in the provider under normal conditions	H_s	The cost of holding a single substance unit S in the supplier of s
ϕ	Production unemployment time in normal conditions	HM_s	The cost of holding a single S in the manufacturer
t_o	The moment of starting period of recovery	H	The cost of holding a unit of product in the manufacturer
t_f	The end of the retrieval period	H_r	The cost of holding a product unit in retail r
T_s	The length of a production period in the provider of S under normal conditions	P_s	Production rate of s
T	The length of a production period in normal conditions	P	Producer rate
T_r	Length of a period of order in Retail r in normal conditions	D_r	Product demand rate in retail r
B_s	The cost of a unit that has been disrupted in the supplier	DM_s	Producer demand rate for the primary substance s
BM_s	The cost of a unit of demand for the initial substance S in the manufacturer	Q_s	Production size in providing s under normal conditions
BM	The cost of a decline unit for the product in the manufacturer	Q	Production size in the manufacturer in normal conditions
B_r	The cost of a unit of product in retail r	V_s	The size of the manufacturer's order to provider S under normal conditions
L_s	The cost of a lost sales unit in the supplier that has been impaired	V	The size of the manufacturer's order that has been disrupted by normal conditions
LM_s	The cost of a lost sales unit for the primary substance S in the manufacturer	V_r	The size of the retail r in normal conditions
LM	The cost of a lost sales unit for the product in the manufacturer	α_s	Parameter indicates the occurrence of disrupting s
L_r	The cost of a lost sales unit in retail r	α_m	The parameter indicates the occurrence of a problem in the manufacturer
Osi	The size of the manufacturer's order to supplying S in my period i recovered period	α_r	The parameter indicates the occurrence of disruption of r retailers

Symbol	Decision variables	Symbol	Decision variables
O_i	The size of the manufacturer's order to provide an impaired provision during the period of the recovery i	TS_i	The length of the production period i in the provision of impaired during the recovery period
O_{ri}	Retail order size r in retrieval period i	T_{si}	The length of the production period i at the provision of s in the recovery period
n_1	The number of courses in the retrieval has been disrupted	T_i	The length of the production period i in the manufacturer in the retrieval period
n_2	Number of courses in retrieval for manufacturer	T_{ri}	The length of the order period i in the r retailer in the retrieval period
z_1	The number of productions that have been disrupted in retrieval for the supplier	I_i	The end level of the supplier period i that has been disrupted during the recovery period
z_2	Number of production in retrieval for manufacturer	I_{si}	The level of the end of the period i provided s in the retrieval period
BL	The amount of demand drop in the manufacturer	IM_i	The level of the end inventory of the period I produces in the retrieval period
BL_r	The amount of demand drop in retail r	MS_i	The size of the provision produced during the recovery period i
LS	The amount of sales lost in manufacturer	M_{si}	Size of supplying s in period i recovered period
LS_r	Sales amount lost in retail r	M_i	Producer size in period i recovered period

3.1.2. The final model

The general model is written as follows. In this model, two objective functions are considered.

$$Minimize Z_1 = \alpha_m.TC_{\alpha_m}$$
$$Minimize Z_2 = \sum_{s=1}^{S}(\alpha_s.TC_{\alpha_s}) + \sum_{r=1}^{R}(\alpha_r.TC_{\alpha_r})$$
$$Subto:$$
$$MS_1 \leq Q_s - q_s$$
$$MS_1 \leq Q_s i = 1.2, \ldots, z_1$$
$$\sum_{i=1}^{z_1} MS_i \leq P_s(n_1T_s - TS_d - \xi_s) - q_s$$
$$\sum_{i=1}^{z_1} M_{si} \leq P_s(n_1T_s - \xi_s) \quad \forall s = 1, \ldots, S$$
$$\sum_{i=1}^{z_2} M_i \leq P_s(n_2T_s - T_d - \varphi) - q$$
$$\sum_{i=1}^{z_1} M_{si} \geq n_1T_s \times DM_s + BL_r \quad \forall s = 1, \ldots, S$$
$$\sum_{i=1}^{z_1} MS_i \geq n_1T_s \times DM_s + LS - q_s$$
$$\sum_{i=1}^{z_2} M_i \geq n_2T \times \sum_{r=1}^{R} D_r - \sum_{r=1}^{R} LS_r - q + Q_{dr}$$
$$\frac{1}{P_s}\sum_{j=2}^{i} MS_j \leq \frac{1}{DM_s}\sum_{j=1}^{i-1} O_j - \frac{BL_s}{DM_s} \quad i = 1.2, \ldots, z_1$$
$$\frac{1}{P_s}\sum_{j=2}^{i} M_{sj} \leq \frac{1}{DM_s}\sum_{j=1}^{i-1} O_{sj}, s = 1, \ldots, S$$
$$\frac{1}{P}\sum_{j=2}^{i} M_j \leq \frac{1}{\sum_{r=1}^{R} D_r}\sum_{j=1}^{i-1}\sum_{r=1}^{R} O_{rj} - \sum_{r=1}^{R}\frac{BL_r}{D_r} \quad i = 1.2, \ldots, z_2$$
$$I_{s0} = I_{sz_1} = 0 \quad \forall s = 1, \ldots, S$$
$$I_0 = I_{z_1} = 0$$
$$IM_0 = IM_{z_2} = 0$$
$$O_{sz_1} = V_s \quad \forall s = 1, \ldots, S$$
$$O_{z_1} = V$$
$$O_{rz_2} = V_r \quad \forall r = 1, \ldots, R$$
$$n_1, n_2, z_1, z_2 \in Z$$

The first objective equation is the issue of the goal, which includes the total cost of manufacturers and the second function function, including suppliers of suppliers and retailers during the recovery period, which is calculated by the occurrence of the disorder during the previous steps.

The two subsequent relationships ensure that the supply rate is lowered by the supplier in any period of supply in ordinary periods. The next two relationships impose the capacity limits of suppliers, and the next relationship considers the production capacity limit. In two subsequent relationships, it is ensured that the total amount of manufacturer's demand for recovery period is assured and the next relationship examines the same as the demand for retailers. The two subsequent relationships show that the manufacturer in any type of disorder delivered its orders in a timely manner and does not suffer. The next relationship expresses timely retailer's orders. The next three relationships ensure that at the beginning and end of the recovery period, the amount of inventory in suppliers and producers is zero. Three subsequent relationships are also considered to ensure the return of the system to the conditions before the disorder. The last relationship also specifies the type of integer variables.

3.2. Model solving technique

In this research, the two-objective LP and Nsgaii technique were used to solve the two-objective model.

3.2.1. Metric LP method

Metric LP method is one of the most efficient methods for solving multi-objective planning models. This method depends on the case, the total power of the first, second, ... relative deviations minimize the goals of their optimal amount. To clarify the algorithm, this method is considered a multi-objective model according to the following relationship.

$$\begin{aligned} &MinorMaxZ(x) = [z_1(x), z_2(x), \ldots, z_k(x)] \\ &Subjectto : g_i(x) \leq b_j; j = 1, 2, \ldots, m \\ &\qquad\qquad x \geq 0 \end{aligned}$$

Step 1: Look at a multi-objective issue as a few single issues. This means that you consider each of the goals and create a new issue with the problem constraints. By solving each single-objective problem, we will receive answers that answer them.

Step 2: The values of other target functions for the answers obtained from the first step are obtained. For example, in a three-objective issue, three single objectives should be resolved. In the first issue, the first goal function is optimized. To do this, the values of the second and third target functions should also be formed for decision-making variables optimized. At the end of this step, a table is like Table 3. This table is renowned to the exchange table.

Table 3: Exchange table for each target function

	z_1 (x)	$z_2(x)$	$\ldots$	$z_k(x)$
x^1	$z_1^*(x^1)$	$z_2(x^1)$	$\ldots$	$z_k(x^1)$
x^2	$z_1(x^2)$	$z_2^*(x^2)$	$\ldots$	$z_k(x^2)$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
x^k	$z_1(x^k)$	$z_2(x^k)$	$\ldots$	$z_k^*(x^k)$

In the table above $\mathbf{x^1}, \mathbf{x^2}, \ldots, \mathbf{x^k}$ The ideal answers are a matter of $\mathbf{k}$.

Step 3: We calculate the following values of each of the target functions.

$$
\begin{aligned}
& Min\gamma = \sum_{i\in B}^{k} S_i \left(\frac{Z_i^* - Z_i}{Z_i^*}\right)^P + \sum_{i\in R}^{k} S_i \left(\frac{Z_i - Z_i^-}{Z_i^-}\right)^P \\
& Subjectto : g_i(x) \le b_j ; j = 1, 2, \ldots, m \\
& \qquad\qquad x_i \ge 0
\end{aligned}
$$

In the above relationship whatever the larger γ, the extent that the target functions totaled its optimal amount. $\gamma =$ Also, in the above relationship, $\mathbf{S_i}$ is the weight of the **i** function. Total weight functions are equal to one. In this target function, the **B** collection represents the **Max** target functions and the **R** collection represents the set of **Min** target functions. **P** is power and is normal. For different values of **P**, pareto replies are formed.

3.2.2. NSGaii technique

This algorithm has become a multi-objective algorithm with a multi-objective algorithm, which instead of finding the best answer, provides a set of best answers that are known as Pareto Front. These two operators are:

1. The operator allocates a criterion for superiority (rating) based on unclassified sorting to population members.

2. The operator holds the diversity of the answer among equal answers.

The NSGAII technique steps are as follows:

1- Production of initial response and structure of chromosomes

For variables of activity number and variables, the initial response is generated randomly. As a result, the structure of the chromosomes is the size of matrix structures with the size of the number of activities, which departments express the variables of the problem. The symbolic form of chromosomes is presented below.

Structure and how to generate random chromosomes

The three chromosomes are defined as follows for each answer. For example, consider a problem with 3 distribution center candidates (M), 10 demand points (node)) N) and 6 cars (K).

Node chromosome and distribution center: Launching or not launching distribution centers and nodes assigned to each distribution center with the help of this chromosome at the beginning of the horizon. For example, above the permutation of M+N numbers is used as follows: In the above

٦	٣	٧	٨	١٢	٥	١	١٠	٢	٤	٩	١١	١٣

chromosome, numbers 1 to N represent the number of demand and numbers N + 1 to N + M represent the number of distribution centers. For example, numbers 11, 12 and 13 respectively represent the distribution center number 1, 2 and 3. The points that are distributed before each center are actually devoted to the distribution center. Note that the last in the chromosome should be filled by the distribution center number. According to the above chromosome:

To the distribution center number 1, 6 nodes, not assigned to the distribution center number 2, 4 nodes and to the distribution center number 3 nodes for visit. Failure to assign nodes to a distribution center means its lack of launch. It is observed that by defining the high chromosome, all modes of launching distribution centers and allocation of nodes can be displayed.

Distribution Center	Visited points					
1	5	1	10	2	4	9
2	6	3	7	8	—-	
3	—-					

Testing the capacity center of the distribution center: For each distribution center, the restrictions are examined. If the values assigned to a distribution center of its capacity, the last node dedicated to the distribution center is covered by the next distribution center. For example, suppose that the above issue is the total demand for nodes of 6, 3, 7 and 8 in the first period of the capacity of the distribution center number 2. In this case, nodes number 8 are assigned to the first distribution center and the node chromosome and the distribution center are rewritten below.

٦	٣	٧	١٢	٨	٥	١	١٠	٢	٤	٩	١١	١٣

If the capacity constraint of the distribution center is violated, the process continues, so that specific values are not exited any distribution center than its capacity. Due to the non-existent process of demand in the following periods, if the limit applies to the first time period, so in the following periods will be observed.

Car chromosome and distribution center: Use or non-use of cars and how they allocate in the chromosom. The values of this chromosome can be changed for each period of time (day). For this chromosome, the permutation of numbers of 1 to M + K is used as below.

٣	٩	٥	١	٦	٧	٤	٢	٨

To allocate cars, the distribution centers are used from the chromosome. In the chromosome above, numbers larger than K represent the distribution center number. As the above chromosome is the allocation of cars in the form below.

Distribution center	car		
1	5	1	6
2	4	2	—
3	3	—-	

It is observed that the third car is not dedicated to any active distribution centers. In fact, the third car based on the chromosome is not purchased. Knot chromosome and car: Routing and sequencing of nodes visited by this chromosome. The values of this chromosome can be changed for each time period (day). To produce this chromosome, the following process is used.

4. Research findings

4.1. Model validation

In this section, in order to investigate the application of the proposed algorithm for solving the design model, a small dimensional issue includes a supply chain with three suppliers, a manufacturer and three retailers, each of the parameters of each of these parameters to describe the table Below is considered. The parameters provided in this section are based on the occurrence of the supplier. In order to measure the validity of the model and obtain awareness of the correct and acceptable solution, this problem has been solved in two ways in the GAMS software and the NSGA II algorithm.

Table 4: Problem input parameters

retail seller			**parameters**	**Producer**	**Produces**	**Supplier**			
3	2	1				3	2	1	
1316	1100	1390	$\mathbf{D_r}$	3950	**P**	3770	3610	3270	$\mathbf{P_s}$
						3380	3150	3400	$\mathbf{DM_s}$

In this section, according to the program written in GAMS and connecting to Excel, at first, the issue is called from the Excel file with OLE functions and then all the examples of the examples we solve as a result in the file. Excel is saved again. In this regard, the customer code is written in some way that all examples can be solved with all numbers. Below are the general description of the Excel file listed. Then the model is solved for 100 examples with random data. These experimental issues were generated by producing random data for parameters, the amount of supply before the occurrence of the disorder and the length of the disturbance period, which is presented in Table 5 parameters to produce random data scales:

Which ultimately uses solving by the GAMS method, the final answer is shown in Figure 2.

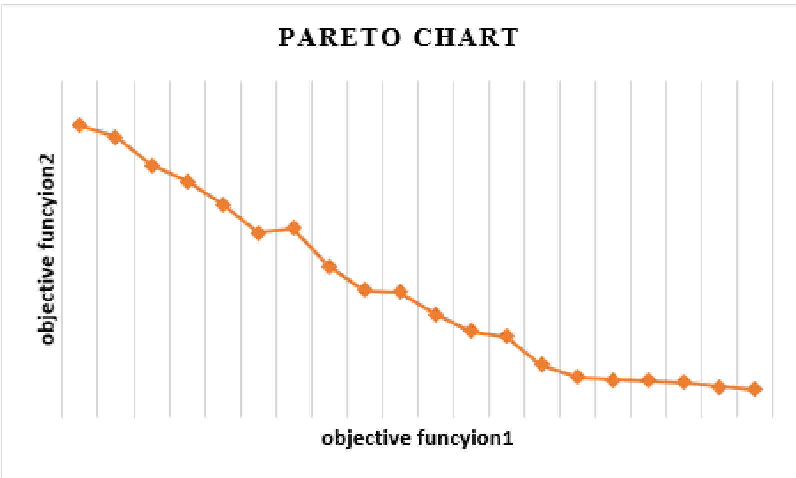

Figure 3: Pareto chart of problem solving in small dimensions with GAMS

Because the issue is to optimize the cost of recovery at the time of disorder. Therefore, the complexity of solving and algorithms is important and the number of parameters and their range is not important to this issue. Because we provide a general algorithm to solve all the issues in this mathematical model, so the number of parameters is not important, but it's important to compare the algorithm and method to solve all the issues from that class. Can be used.

Due to it, it is observed in a hundred and fifty repetition times to optimized answers that will remain constant with more frequent frequency. The decision maker, by choosing any of the non-defeated responses, will have a collection of unique answers that the recovery program is determined after the disorder accordingly. Figure 3 shows optimal answers in this section.

Table 5: Parameters range to generate random data

retail seller			**parameters**	**Producer**	**Produces**	**Supplier**			
3	2	1				3	2	1	
[10 50]	[12 59]	[9 65]	$\mathbf{A_r}$	[195 380]	**AS**	[260 580]	[165 490]	[85 420]	$\mathbf{A_s}$
						[160 590]	[175 530]	[100 440]	$\mathbf{AO_s}$
[4 9]	[3 12]	[4 10]	$\mathbf{H_r}$	[5 12]	**H**	[3 10]	[4 13]	[5 15]	$\mathbf{H_s}$
						[3 10]	[4 13]	[5 15]	$\mathbf{HM_s}$
[13 72]	[15 78]	[12 75]	$\mathbf{B_r}$	[10 80]	**BM**	[15 100	[12 85	[10 90]	$\mathbf{B_s}$
						[15 100]	[12 85]	[10 90]	$\mathbf{BM_s}$
						[25 140]	[20 105]	[15 100]	$\mathbf{L_s}$
[50 90]	[55 130]	[45 120]	$\mathbf{L_r}$	[30 100]	**LM**	[25 140	[20 105	[15 100]	$\mathbf{LM_s}$
								[ξ $\mathbf{T_s}$	$\mathbf{TS_d}$
								[**0** $\mathbf{Q_s}$]	$\mathbf{q_s}$

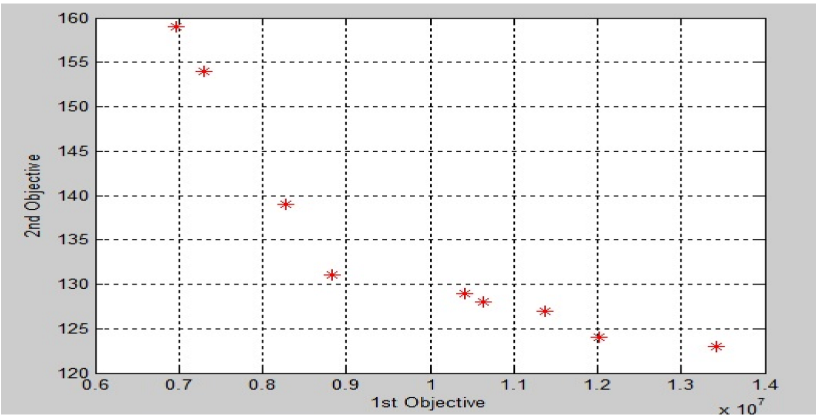

Figure 4: Optimal answers by considering the situation

In order to investigate the approach used in this study, the assumptions of sample issues were used. The present study was solved from two methods of solving in Gutt software and multi-objective genetic solving method in MATLAB software, which was solved by the first method showing the validity of the model and the results of the implementation of the frequency algorithm. Solving by the exact method for a problem with a small sample is possible and it is not possible to solve the model for large issues in the real world because it is significant to solve a small problem with GAMS software. While solving the model by MATLAB software, using the genetically lower genetic algorithm, it has been removed and allowed in solving a larger scale (Table 6).

The following chart represents this issue. As shown below, by changing the first target function, the second target function moves in the opposite direction. This means that by increasing the value of the first target function, indicating the manufacturer's costs, the second target function, which represents the cost and retail costs, decreases. This process is also reversed. That is, by reducing the cost of production costs, retail sales costs and supply. Although the ratio of these changes is not the same and the ratio of changes is nonlinear, but nevertheless shows the conflict between goals. This point is to confirm the hypothesis of the researcher than several objects of the problem, and that goals are in conflict.

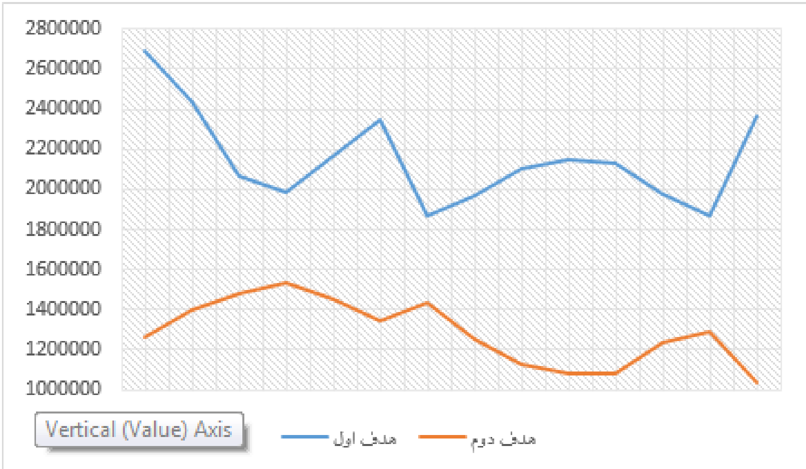

Figure 5: Analysis of the process of changes in the first target function and the second target function

Regarding the two objectives of the model, we solve by using a weighted metric method and considering weight for each of the goals. By default, the Metric LP model considers 0.5 for each of the functions of the goals and calculates the model in power. In order to verify other results, in the following functions were given from zero to 100. This means that total weight 1 was calculated with different ratios.

W1	0/55	0/45	0/5	0/4	0/7	0/3	0/6	0/65
W2	0/45	0/55	0/5	0/6	0/3	0/7	0/4	0/35

Based on the results, according to the status and importance of two objectives, the target function will be decided. The results are in accordance with the following tables.

Table 6: Problem input parameters

Percentage of deviation	The value of the second target function		The value of the first target function		Z2	Z1	n2	n1	L_r	B_r	H_r	A_r	LM	BM	H	AS	TS_d	LM_s	L_s	BM_s	B_s	HM_s	H_s	AO_s	A_s	ROw
	NSGA-II	GAMS	NSGA-II	GAMS																						
0000 1/0 %	1263 255	1263 254	2684 425.5	2568 425	6	5	3	2	45	26	3	15	40	20	6	325	0031 /0	25	25	23	25	2	6	241	327	1
0000 2/0 %	1236 543	1263 542	2435 266	2435 267	7	6	2	3	58	28	5	65	45	36	3	285	0026 /0	35	62	25	26	3	5	287	310	2
0000 1/0 %	1250 360.8	1250 361	2070 367	2070 368	6	5	3	1	56	63	3	63	68	25	8	269	0036 /0	40	63	26	24	6	6	203	150	3
0000 1/0 %	1236 411.5	1236 412	1986 211	1986 210	8	6	2	3	65	45	6	52	63	40	5	315	0053 /0	45	67	47	23	5	8	206	168	4
0000 2/0 %	1150 366	1150 367	2163 244.5	2163 245	6	7	2	2	75	57	3	64	54	79	4	364	0016 /0	47	58	46	25	6	6	265	175	5
0000 3/0 %	1246 236	1246 235	2348 719	2348 721	5	8	3	4	68	63	5	52	59	72	6	425	0071 /0	58	59	12	63	8	12	237	342	6
0000 1/0 %	1168 359	1168 360	1863 235	1863 236	6	6	4	2	85	26	2	57	57	68	9	469	0072 /0	64	26	25	24	7	10	258	452	7
0000 2/0 %	1254 862	1254 863	1963 745.8	1963 746	5	5	2	3	86	34	3	60	68	64	8	478	0063 /0	53	24	26	27	6	4	342	486	8
0000 3/0 %	1325 648	1325 647	21028 846.25	21028 846	6	6	3	2	82	43	5	36	62	25	5	429	0051 /0	57	28	28	28	4	8	345	427	9
0000 2/0 %	1256 348	1256 349	2150 366	2150 367	4	4	2	4	46	45	3	38	64	56	5	268	0023 /0	59	23	36	65	6	3	362	236	10
0000 3/0 %	1230 216	1230 215	2130 688	2130 687	6	5	3	3	52	62	4	42	63	58	6	381	0018 /0	86	25	34	81	6	8	238	461	11
0000 2/0 %	1240 233	1240 231	1976 202	1976 201	5	6	2	3	55	36	6	26	65	51	8	296	0057 /0	58	28	50	83	5	9	425	356	12
0000 2/0 %	1200 367	1200 364	1867 563.8	1867 564	8	4	2	2	68	24	5	29	58	36	4	284	0061 /0	23	83	53	36	4	14	421	520	13
0000 2/0 %	1238 641.8	1238 641	2367 541.7	2367 542	6	5	3	3	73	25	3	22	86	35	5	267	0084 /0	36	71	54	26	2	12	403	423	14
0000 2/0 %	1236 411.5	1236 412	1986 211	1986 210	5	6	2	4	70	25	3	15	36	38	9	255	0083 /0	34	76	57	28	3	6	326	214	15

Table 7: Results of problem solving by LP-METRIC method with considering **p=1**

W1	0/55	0/45	0/5	0/4	0/7	0/3	0/6	0/65
W2	0/45	0/55	0/5	0/6	0/3	0/7	0/4	0/35
$\mathbf{A_s}$	236	427	486	452	342	175	168	150
$\mathbf{AO_s}$	362	345	342	258	237	265	206	203
$\mathbf{H_s}$	3	8	4	10	12	6	8	6
$\mathbf{HM_s}$	6	4	6	7	8	6	5	6
$\mathbf{B_s}$	65	28	27	24	63	25	23	24
$\mathbf{BM_s}$	36	28	26	25	12	46	47	26
$\mathbf{L_s}$	23	28	24	26	59	58	67	63
$\mathbf{LM_s}$	59	57	53	64	58	47	45	40
$\mathbf{TS_d}$	0/0023	0/0051	0/0063	0/0072	0/0071	0/0016	0/0053	0/0036
AS	268	429	478	469	425	364	315	269
H	5	5	8	9	6	4	5	8
BM	56	25	64	68	72	79	40	25
LM	64	62	68	57	59	54	63	68
$\mathbf{A_r}$	38	36	60	57	52	64	52	63
$\mathbf{H_r}$	3	5	3	2	5	3	6	3
$\mathbf{B_r}$	45	43	34	26	63	57	45	63
$\mathbf{L_r}$	46	82	86	85	68	75	65	56
n1	2	1	3	2	1	3	2	3
n2	2	3	2	2	2	2	1	3
Z1	5	6	5	6	5	6	6	7
Z2	8	5	4	5	6	5	6	7
LP-Metric function	0/108	2/127	0/136	0/ 163	0/156	0/231	0/3212	0/208
The value of the first target function	2435267	2356842	2364125	2236581	2306741	2150742	2200364	2163425
The value of the second target function	1325752	1234680	1263842	1150638	1234225	1321421	1335412	1263421

Table 8: Results of problem solving by LP-METRIC method with considering **p=2**

W1	0/55	0/45	0/5	0/4	0/7	0/3	0/6	0/65
W2	0/45	0/55	0/5	0/6	0/3	0/7	0/4	0/35
$\mathbf{A_s}$	236	427	486	452	342	175	168	150
$\mathbf{AO_s}$	362	345	342	258	237	265	206	203
$\mathbf{H_s}$	3	8	4	10	12	6	8	6
$\mathbf{HM_s}$	6	4	6	7	8	6	5	6
$\mathbf{B_s}$	65	28	27	24	63	25	23	24
$\mathbf{BM_s}$	36	28	26	25	12	46	47	26
$\mathbf{L_s}$	23	28	24	26	59	58	67	63
$\mathbf{LM_s}$	59	57	53	64	58	47	45	40
$\mathbf{TS_d}$	0/0023	0/0051	0/0063	0/0072	0/0071	0/0016	0/0053	0/0036
AS	268	429	478	469	425	364	315	269
H	5	5	8	9	6	4	5	8
BM	56	25	64	68	72	79	40	25
LM	64	62	68	57	59	54	63	68
$\mathbf{A_r}$	38	36	60	57	52	64	52	63
$\mathbf{H_r}$	3	5	3	2	5	3	6	3
$\mathbf{B_r}$	45	43	34	26	63	57	45	63
$\mathbf{L_r}$	46	82	86	85	68	75	65	56
n1	2	1	3	2	1	3	2	3
n2	2	3	2	2	2	2	1	3
Z1	5	6	5	6	5	6	6	7
Z2	8	5	4	5	6	5	6	7
LP-Metric function	0/169	0/136	0/152	0/ 169	0/141	0/218	0/316	0/235
The value of the first target function	2436263	2136525	2201364	2151242	2307041	2236681	2361125	2346842
The value of the second target function	1256321	1336412	1322361	1244225	1151038	1262842	1224680	1315740

Based on the results, it was found that the values of the metric lp with the same values in different weights and power 1 and 2 are different.

4.2. Model sensitivity analysis

To investigate and analyze the sensitivity of the model, appropriate samples from randomized issues have been used in the previous section, so that all parameters were assumed on the middle value of the defined interval and variable variations were designed, which showed the results of the model Can resolve issues. In this section, the sensitivity analysis of the model has been addressed. Sensitivity analysis indicates whether the model works properly? And is the model sensitive to increasing or reducing some parameters?

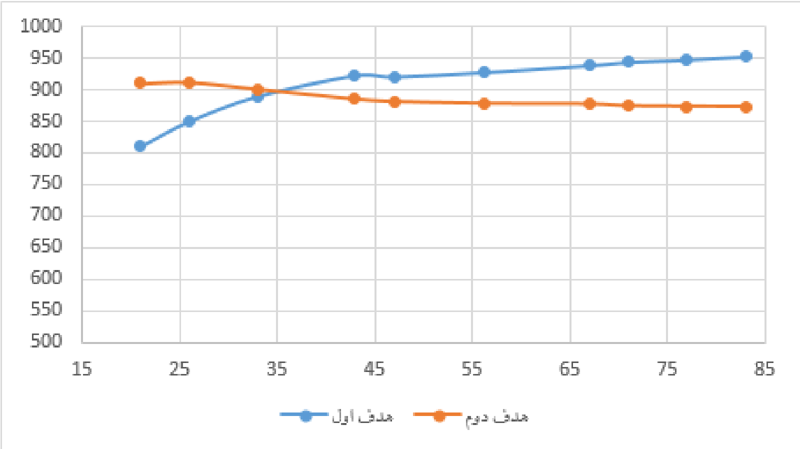

Figure 6: Total recovery cost changes in the first and second target function based on fixed cost change changes

By increasing the fixed cost of retail order in the second target function that has been disturbed, the total recovery fee in the second target function increases and in the second target function, it is almost reduced that the slope of this increase in the second target function is gentle and almost linear and in The first target function is nonlinear. The cause of this behavior can be capacity constraints that, despite the desire of the model, to reduce the number of orderings, due to increasing fixed costs, naturally determines the limitations based on constraints. In the following, the cost of recovery of disruption based on the amount of destroyed commodity due to disturbance and sensitivity of the model has been shown to increase this cost.

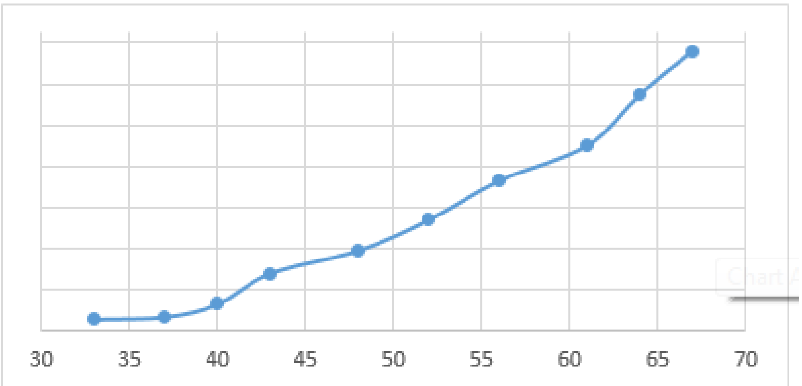

Figure 7: Changes for the cost of recovery of disorder based on the amount of destroyed goods in the effect of disorder

The retrieval status of the total cost of supply chain recovery, which includes the sum of the first target function and the second target function, is shown in the following figure according to the amount of disorder. In the event of an increase in the amount of product destruction, the cost of recovery of these two target functions increases with a significant gradient, which has been obvious and predictable. Because it is expected to increase the cost of recovery, manufacturer and retailer of all three.

Another sensitivity analysis that is considered is related to the cost of restoring the target function (manufacturer) and the second target function (supplier and retailer) due to the change in the cost of maintaining inventory in retail that disruption is created.

By reducing the cost of maintenance, the total cost increases. The decreasing process of the

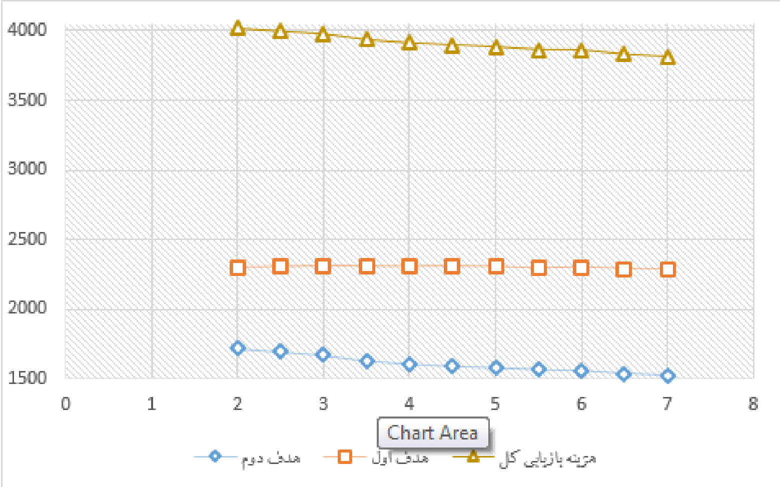

Figure 8: Changes in the cost of retrieval function of the first and second target based on the cost of maintenance cost of inventory in disrupted retailers

second target function, although it is not a sharp slope and is almost linear, but a significant point. This process is very small in the first target function. In total, the cost of recovering the whole supply chain is similar to the second target function. This chart suggests that in the presented model, the focus of its chain behavior and its decisions are based on inventory, and as shown before, the number of recovery courses is low. Therefore, the importance of maintenance costs in deciding more than other types.

4.3. Real issue of Iran Khodro

In this section, in order to solve the multilevel supply chain recovery problem, after disturbance in the Iranian supply chain, a real issue of supplier disorder in the Iranian supply chain has been investigated.

Undoubtedly, one of the reasons that made the market component is inflamed, the problems associated with sequesters, as well as the arrival of pieces to the country. In the case of plugs and obstacles in the supply of raw materials, these problems have caused the components required for production lines as well as supplying part of the market needs. One of the main problems in delivering automated vehicles, many of which are ready to be delivered, but there are parts in the gearbox that domestic suppliers should supply it, but one of the components that the company worked with. The piece has been shortened and has acted on the delivery of essential parts for several reasons. This disability has disrupted the entire supply chain of Iran, which is more accurately modeled in this section, with the proper response to disruption. In the following, by studying more detailed information from this chain, providing a retrieval program. The supply chain data studied is presented in the following tables. Corporate names have been removed for Iran's Iran-based reasons.

Table 9: Problem input parameters

The cost of selling unit lost in case of disruption	The unit cost of the fragment drop in case of disorder	Total production	Storage cost of piece	Fixed setup Cost	Suppliers of the desired piece
5100	4150	1150	12	3500	Supplier 1
5240	4170	2150	11	2500	Supplier 2
5900	3990	2500	13	3000	Supplier 3
6100	4150	2500	15	2750	Supplier 4
5700	3995	2175	12	3000	Supplier 5

Table 10: Iran Khodro Information in the Supply Chain

Parameter	Number	Parameter	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Fixed setup Cost	3290	Fixed cost order	16	11	14	14	15
Storage cost of piece	14	Storage cost of piece	21	20	22	21	19
Total production	21200	The demand rate of the piece	1288	2408	2800	2800	2436
The unit cost of the piece after decreasing demand	10000	The unit cost of the piece after decreasing demand	6500	4500	5500	6000	7200
Lost sales unit cost	95000	Lost sales unit cost	58500	51900	55000	43900	53200

By entering the above parameters in the two-objective model, designed and solving it through the innovative algorithm provided in the research, the values of the decision variables were calculated and the following table was presented:

According to the results, it is determined that the occurrence of an impairment in one of the suppliers can disturb the production plan of the supply chain to the specified extent, and when the disorder is corrected, the retarded production process to the period The next passes and its recovery in the next periods will continue with the dysfunction of the subsequent periods of up to 15 courses, and then its impact will be resolved, which can be expressed by taking 1 year production periods that the impact of sanction and lack of The production of the produced piece has remained up to 15 years in the system and can disrupt this system without increasing production capacity and will recover the production system for 15 years.

Table 11: Retail information in the supply chain studied

Lost sales unit cost	Unit cost after product drop	Order number	Product storage cost	Fixed cost order	Representation
82000	12000	3200	15500	8000	Tehran
80000	11000	2800	11000	8400	Esfahan
80000	11200	3000	10500	9300	Shiraz
65000	10800	2000	12000	10200	Tabriz
71000	11000	1300	11400	10500	Mashhad
69000	11500	1000	12400	14500	Ahwaz
62000	10200	650	10900	8500	Qazvin
65000	11000	750	10500	8100	Qom
73000	12000	1200	11700	11500	Kerman
69000	10500	750	11000	9800	Yazd
61000	9500	350	10200	10200	Lorestan
70000	10500	550	11000	11000	Ardabil
75000	11000	650	11500	11500	Orumieh
72000	9900	550	9900	10000	Kermanshah
81000	12000	650	12000	9500	Rasht
75000	8200	400	8900	15000	Zahedan
72000	9500	550	9700	9200	Arak
73000	9850	350	9500	9000	Hamedan
75000	8200	300	10000	14500	Bandar Abbas
72500	9000	250	9800	9100	Zanjan
82000	11000	350	10200	9500	Sari
78000	10000	300	9800	10200	Shahr e Kord
72500	10200	250	9500	9500	semnan

Table 12: The values of the decision variables obtained from the two-objective model solving using the proposed algorithm

<table>
<tr><th colspan="6">Manufacturer Information</th><th colspan="4" rowspan="2">The supplier information that has an impaired</th><th colspan="2" rowspan="2">General supply chain information</th></tr>
<tr><th>Total production</th><th>Recovery period</th><th>Total production</th><th>Recovery period</th><th>Total production</th><th>Recovery period</th></tr>
<tr><td>125</td><td>11</td><td>210</td><td>6</td><td>310</td><td>1</td><td>35</td><td rowspan="3">The size of the supplier's production is impaired during the recovery period</td><td>1</td><td rowspan="3">Recovery period number</td><td rowspan="2">3</td><td rowspan="2">Number of courses on recovery horizons for supplier and retailer</td></tr>
<tr><td>120</td><td>12</td><td>155</td><td>7</td><td>310</td><td>2</td><td>150</td><td>2</td></tr>
<tr><td>115</td><td>13</td><td>135</td><td>8</td><td>310</td><td>3</td><td>105</td><td>3</td><td>12</td><td>Number of courses on the recovery horizon for the manufacturer</td></tr>
<tr><td>94</td><td>14</td><td>110</td><td>9</td><td>289</td><td>4</td><td>109</td><td></td><td>4</td><td></td><td>5</td><td>The frequency of production in the recovery period for the supplier has a disorder</td></tr>
<tr><td>110</td><td>15</td><td>110</td><td>10</td><td>275</td><td>5</td><td>210</td><td></td><td>5</td><td></td><td>15</td><td>The number of production in the recovery period for the manufacturer</td></tr>
</table>

5. Discussion and conclusion

In this research, according to previous studies, some parameters and variables were identified and then based on the main problem, the two-objective mathematical model was designed to reduce cost in the manufacturer and supplier and retailer. After designing a mathematical model, the model validity was first confirmed. Thus, the model was dissolved for random intervals and various issues, and then the results of the model were examined and it was found that the model has the ability to solve and determine costs. According to the results, it was found that by determining the parameters in the model in different issues, the variables can be measured and identified the costs and recovery time of the disorder, and accordingly the model can also help participate for other issues.

After examining the results and identifying the points of participation and the differentiation of the present study by previous research, it will continue to provide some suggestions for managers and decision makers in Iran Khodro to enhance and upgrade the level of performance and supply chain activity.

- It is suggested that company managers use the mathematical modeling approach and scientific decision making to improve the level of activity and performance of the supply chain of Iran Khodar car, because some cross-sectional decisions, regardless of the impact of decision-making in the whole chain, may cause Removable works and long-term disorder in the system. Therefore, the use of the model designed in the present study, while considering different intervals for parameters, can examine the effects of disruption and decisions in different levels of supply chain.
- It is suggested that pre-occurrence managers and in order to increase the supply of the supply chain system of Iran Khodro, using techniques such as simulation and analysis of scenario and model based on the present study, various events that are close or away from Check the mind and prepare the company to deal with these events. The prediction of events can be prepared to cope with it and reduce the effects of disruption.
- According to the critical conditions of the Iran Khodro company and its suppliers, it is suggested that Iran's Iran-based company, based on the type of disorder, adopts solutions to compensate disruption and reduce its effects on the system and reduce the recovery time of the system. These strategies can include setting new contracts with new suppliers, providing proposals for manufacturers of parts and shifts their products towards the essential and required parts of the company, import some parts from the countries of China and Turkey and replace imported parts with current parts Design to change the use of some parts and several use of its use.
- The managers are suggested to provide joint meetings with their suppliers to create more readiness to deal with possible disruptions in the supply chain so that they can obtain information from their functional interval and potential disorders of changes in different cost intervals To remind them.
- It is suggested that Iran's car companies, in the strategic planning unit of the organization, have been monitored by internal and external events and calculated with scenario for events, the effects of disorders and recovery periods using the mathematical model designed in the present study. View.
- The managers are suggested by holding meetings in the Industrial Engineering Unit and Planning, the model designed in the present research and enter the parameters and variables and more precise intervals.

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