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Provide a multi-objective mathematical model to achieve a green supply chain to a sustainable supply chain taking into account the social dimension

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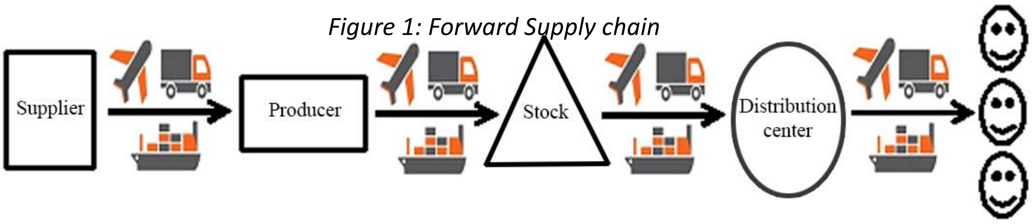
Abstract.
Organizations have been forced to change attitudes in supply chain management after facing several factors such as rising levels of outsourcing, rising transportation costs, competitive pressures, and globalization. The desire of customers, the pressure of nature-friendly groups, international and governmental organizations that support the environment has caused organizations to pay attention to issues related to environmental management and energy. To solve these problems, green supply chain management was introduced, which aims to minimize waste and emit pollutants along the supply chain. Due to the importance of this issue, in the present study entitled "Presenting a multi-objective mathematical model for green supply chain management to achieve a sustainable supply chain", an attempt has been made to consider three economic, environmental, and social dimensions of sustainable development. Model and make decisions at the supply chain planning and design level and achieve a sustainable supply chain model. Most studies in the field of the sustainable supply chain have provided general definitions and in case of further modeling, attention has been paid to economic and environmental fields. Therefore, the present study tries to look at the issue with a more comprehensive and practical view and to model and optimize all dimensions of supply chain sustainability. Generally, in the supply chain literature, more research has been done on two dimensions of sustainability (either economic and environmental or economic and social). Articles dealing with all three aspects of sustainability require little research. Also, in such articles, a small number have done mathematical modeling and in this area of literature, combos are felt. This article pays special attention to the third dimension of sustainability, namely social sustainability. Finally, using random data, the model is solved in Gomez and the results are presented in the form of a numerical example. The presented results show that the mathematical model is applied and can be used for real problems and give optimal answers.
Keywords: Sustainable supply chain, Multi-objective mathematical modeling, Sustainable Development, Green supply chain, Social Dimension

1. Introduction
In the 1980s, as diversity in customer-expected patterns increased, organizations became increasingly interested in increasing flexibility in product lines and developing new products to meet customer needs. In the 1990s, along with improvements in production processes and the application of reengineering patterns, managers in many industries realized that not only improved internal processes and flexibility in the company's capabilities were sufficient to continue to be present in the market, but also suppliers of parts and materials. Produce with

the best quality and lowest cost, and distributors of products must be closely related to the development policies of the producer market (Jafarnejad & Mahmoudi, 2015).

Fig.1 shows a forward supply chain. Each supply chain starts with the supplier and ends with the end customers, and there is a flow of materials and information between the two members, and different vehicles are responsible for communication between the members.

Figure 1: Forward Supply chain



In the model proposed in this research, we are faced with the allocation of equipment and transportation options. We have a five-pronged supply chain, including suppliers, manufacturers, warehouses, distribution centers, and customers. In fact, the problem is that to meet customer demand for a particular product, we seek to create an optimal sustainable supply chain. With the performed analyzes, points for creating facilities have been identified In other words, several alternatives have been obtained for setting up production units, warehouses, and distribution centers, along with estimating fixed and variable costs of creating facilities anywhere. There are also several suppliers to supply the raw material needed for production. Between these facilities, there are various transportation options that, depending on the geographical location of the alternatives, it is possible to communicate through a maximum of three methods: land, air, and sea. The issue of choosing from suppliers and determining the amount of purchase of each manufacturer from each of them, selecting manufacturers, warehouses, and distribution centers from the available alternatives, and determining the amount of supply of their demand from each of their upstream facilities, with Attention to economic, environmental and social goals. Also, based on the distance between the facilities and the number of hazardous gases produced from each of the transportation options, the appropriate transfer method is determined. The proposed model assigns a shipping option to each open facility.

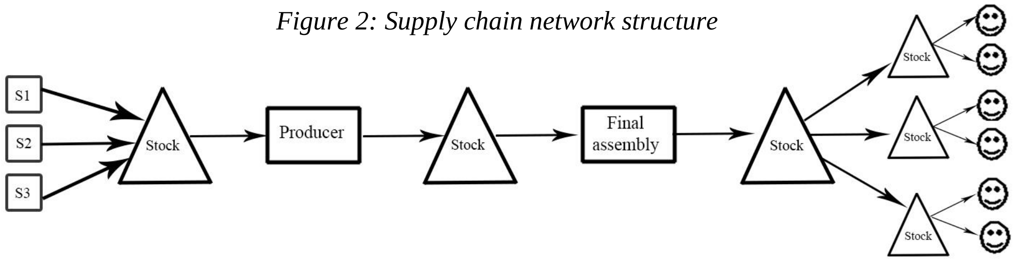
2. Literature review

2.1 Supply Chain Management

The complexity of goods and services in today's world is such that few organizations or institutions can produce or provide products alone or without the help and cooperation of other organizations. Raw material suppliers and parts manufacturers, who themselves are in contact with the suppliers of required raw materials, provide the raw materials and parts necessary to produce a product to the organization that produces the product, and the organization, after producing the product, Distribution channels help deliver their product to customers (Mottaghi & Hosseinzadeh, 2009).

Fig.2 shows a supply chain network. As shown in the figure, the supply chain network consists of many divergent and convergent currents that complicate the network.

Figure 2: Supply chain network structure



Source: (Stadtler & Kilger, 2005)

The most popular definition of a supply chain is as follows: A system of suppliers, manufacturers, retailers, and customers, in which materials flow from suppliers to customers downward, and information flows from both sides. A supply chain is a network of equipment and distribution points that converts materials into semi-finished and finished products and delivers the final products to customers (Lee & Billington, 1993). The term "supply chain management" first appeared in the literature by Keith and Webber. From the perspective of these two researchers, a supply chain seeks to make logistics a major management concern. Whereas only senior management can solve and balance conflicting task objectives throughout the supply chain; An integrated systems strategy that reduces the level of risk is developed and implemented. In their view, coordinating material, information, and financial flows in a large multinational corporation is a difficult and challenging task (Jafarnejad et al., 2018).

2.2 Green Supply Chain

Rising concerns about environmental warnings are forcing manufacturers to try to implement environmental management strategies. Perspectives such as green supply chain management, green productivity, green production, and environmental management systems have been applied to green management activities. Meanwhile, since adverse environmental effects occur at all stages of the product life cycle and the management of environmental programs and operations is not limited to the organization, understanding environmental responsibility leads to competitive advantage and increased market share through the process of improving the environmental impact of products (Zhu & Sarkis, 2006). Market and competitors are one of the drivers of the organization towards accepting green supply chain management. In today's global business, competition between organizations is fierce, and to influence customers, organizations need to position themselves ahead of competitors. Being environmentally friendly and adapting to environmental requirements is a way to differentiate yourself from other competitors. If competitors have benefited from green supply chain management, the company will be under more pressure to establish green supply chain management (Demeter et al., 2007).

A summary of the definitions is given in Tabl.1:

Table 1: Green supply chain definitions

Author	Year	Define
Zhou et al	2005	an important new paradigm for companies to achieve profit and market share goals by reducing their environmental risks and impacts while increasing their environmental efficiency.
H'mida & Lekhal	2007	Monitoring and improving environmental performance in the supply chain throughout the product life cycle.
Salem Y. Lakhal	2007	The Olympic Green Supply Chain is defined by the flag of the 5 Olympic Circles as zero emissions, zero waste on activities, zero waste, zero use of toxic substances, zero waste on the product life cycle, in addition to green inputs and green outputs.
Elbino	2009	A strategic approach to the development of environmental measures for the entire supply chain.
Gawronski	2011	A set of mechanisms implemented at the company and factory level to evaluate and improve environmental performance from the source base.
Lou	2011	Integrating environmental thinking with closed-loop supply chain management.
Wu & Pagell	2011	The environmental dimension of sustainable development in the field of the supply chain.
Gonnouni	2011	It is a method that aims to integrate environmental issues into supply chain management starting from product design and continuing through sourcing and selection of materials, production processes, final product delivery, and end-of-life management.
Kidick	2012	A way for companies to achieve profit and market share goals by reducing environmental impact and increasing environmental productivity.
Andik	2012	Minimize and preferably eliminate the negative effects of the supply chain on the environment.

2.3 Sustainable Development

In 1987, the World Commission on Environment and Development (WECD) provided a seminal definition of sustainable development, which has become the landmark for countless governments, businesses, and civil society organizations to contribute to a sustainable world. And yet, it is precisely the nuanced approach of the WECD – focusing simultaneously on the protection of nature, the creation of economic welfare, and social inclusion that threatens the boundaries of the Earth system. Governments and enterprises fail to respect the planetary boundaries. Hence, they compromise the ability of future generations to meet their needs. Their focus on economic value creation for present generations ignores to a large extent the potential consequences for generations to come and creates a 'tragedy of the commons'. As a result, many enterprises unjustifiably picture themselves as contributing to sustainable development (Hummels & Argyrou, 2021).

According to the general definition, sustainable development means coordination and adaptation to various aspects of the welfare of human society, ie the economic, social, and environmental dimensions in the long run. In 1987, a report was published by Brundtland, which led economic policymakers to gradually incorporate the concept of sustainable development into their decisions. According to the report, sustainable development is defined as "sustainable development that meets the needs of the present generation." "So that future generations will be able to meet their needs and wants equally." In simpler language, sustainable development is sustainable development (Committee, 2001). Achieving sustainable development requires a balance between the interests of the present generation and future generations. The performance of the present generation will inevitably affect the number of assets and resources of future generations. Irregular economic growth Although it may inherit more economic assets for our children, it severely exposes natural and environmental resources to extinction. The main goal of sustainable development is to strike a balance between the qualitative and quantitative aspects of economic growth.

Figure 3: Changing attitudes towards development in sustainable development

Sustainability consists of three parts: society, the environment, and the economy, all of which are interrelated. Organizational community is a complex human interaction to which we today depend entirely. Thus, the sustainability of communities is a necessary condition for estimating human needs. Social factors will be key components of the legacy of future generations and are therefore important for achieving sustainability. Successful factors also determine the current quality of life, of which availability is an important factor. The environment deals with humans and other forms of life and limits human activities to the least irreversible damage to the environment.

Economics describes the resources available and how these resources are allocated to estimate human needs and goals. In general, economic factors have a significant impact on the environment and society (Malek & Kamali, 2013). The goal of supply chain management is to remove barriers, reduce cycle time, and inventory to provide better customer service at the lowest cost. In 2000, it became necessary for a company to not only involve suppliers and customers in the supply chain but also to consider the interests of stakeholders, including the community, government, NGOs, and other stakeholders. The idea that in addition to achieving economic goals, a supply chain should have socially and environmentally responsible behavior led to the birth of the concept of sustainable supply chain management (Mitra & Datta, 2013).

2.4 Sustainable Supply chain Management

Sustainable supply chain management is the management of operations, information resources, and supply chain financial resources to maximize environmental impacts and maximize social welfare. Social welfare in this definition means supply chain behaviors with employees, customers, and society in general (Hassini et al., 2012). This definition refers to the fact that companies face many challenges. Dealing with multiple decision-makers and assessing the environmental impact and social benefits of a multi-sectoral supply chain is one of the serious challenges for managers in sustainable supply chain management (Seuring & Müller, 2008). Although the concepts of sustainable supply chain management and green supply chain management are often used interchangeably in the supply chain literature, the two concepts are different. Sustainable supply chain management includes three dimensions: economic, environmental, and social. Therefore, the concept of sustainable supply chain management is broader than green supply chain management (Farahani et al., 2009). We can also mention the new definition of sustainable supply chain management: "Creating a coordinated supply chain, by voluntarily integrating economic, environmental and social considerations with intra-organizational business systems, for the efficient and effective management of key materials, information and flows related to the purchase, production, and distribution of products or services to meet stakeholder needs. And increase the profit and competitive advantage and sustainability of the organization in the short and long term" (Ahi & Searcy, 2013).

3. Materials and Methods

Economic modeling is a common concept and applies to almost all supply chain issues. But from an environmental point of view, this issue is worth considering. There are two approaches to this dimension:

1- Estimating the number of emissions of dangerous gases and trying to provide a solution that, in addition to reducing the cost, also reduces the number of emissions.

2- Estimating the cost of emitting hazardous gases. In this case, this function can be combined with the economic function and in fact, have a cost type function that aims to minimize.

Some tables and standards make it easy for us to use these approaches. They have calculated the amount of emission per unit distance and per unit volume of cargo for different vehicles. Or they have calculated the cost of emissions by considering costs such as carbon tax. In this research, the first approach is selected. Because the cost of publishing may not really be covered by costs such as taxes. Our goal should be to reduce emissions, although at no cost to emissions. As if the carbon tax law and similar laws have not yet been adopted in many countries. But in the case of the third dimension of sustainability, namely social costs. The complexity of this dimension is far greater than the environmental dimension. Because it is related to human rights and working conditions and social supply chain. Concepts that are completely qualitative and cannot be easily quantified. Therefore, integrating this dimension with other dimensions of sustainability is difficult and does not seem logical.

Our goal is to consider and optimize all three dimensions, but as mentioned, the objective functions of the problem are different. Studies show that they are closer in terms of their ability to quantify economic and environmental functions, but the social dimension is different. Therefore, it was decided to model a sustainable supply chain in two parts. The first part of the modeling is dedicated to the simultaneous optimization of economic objective functions (with the approach of minimizing costs) and environmental (with the approach of reducing greenhouse gas emissions). In this section, a set of answers is obtained according to the coefficient of importance given to the two economic and environmental functions in contrast. Then choose from the answers based on social.

3.1 The mathematical model for optimizing the economic and environmental objective function

Because in addition to economic goals and cost reduction, we also pursue environmental goals, our model is a multi-objective model. Considering the hypotheses mentioned in the next section, our problem is of the type of linear programming of an integer mixed with two objectives.

- **Sets:**

C: Customer Collection
D: Collection of distribution centers
W: warehouse collection
M: Manufacturers Collection
S: the set of suppliers
K: the set of means of transport for the facility

- **Parameters:**

dem_c : Customer demand c

dem_f : Facilitation request f belongs to {m, w, d}

cr_{sm} : Unit cost of raw materials from the supplier s to producer m

c_{sm}^k : Shipping unit cost from supplier s to manufacturer m with shipping option k

c_{mw}^k : Shipping unit cost from manufacturer M to warehouse w with shipping option k

c_{wd}^k : Cost of transport unit from warehouse w to distribution center d with transport option k

c_{dc}^k : The cost of the transport unit from the distribution center d to the customer c with the transport option k

$dis_{ff'}$: Distance between equipment f belonging to {s, m, w, d}, and equipment f' belonging to {m, w, d, c}

f_{c_f} : Fixed cost of setting up facilitation f belongs to {m, w, d}

vc_f : The variable cost of the facilitation unit f belongs to {m, w, d}

P : Penalty for a unit of unmet customer demand

ca_f : Facilitation capacity f belongs to {s, m, w, d}

ca^k : Transportation capacity

G_N^k : Nitrogen dioxide emission rate per unit distance for vehicle k

G_C^k : Carbon monoxide emission rate per unit distance for vehicle k

- **Variables:**

x_S : If supplier s is open it is equal to 1, otherwise, it is equal to 0.

x_m : If supplier m is open it is equal to 1, otherwise, it is equal to 0.

x_w : If the warehouse w is open it is equal to 1, otherwise, it is equal to 0.

x_d : If the distribution center d is open, it is equal to 1, otherwise, it is equal to 0.

x_{sm}^k : The number of products transferred from the supplier s to manufacturer m using transport k

x_{mw}^{k} : The number of products transferred from producer m to warehouse w using transport k

x_{wd}^{k} : The number of products transferred from the warehouse w to the distribution center d using transport k

x_{dc}^{k} : The number of products transferred from the distribution center d to the customer using transport k

- **Mathematical model:**

As mentioned, The model has 2 objective functions and each objective is divided into different components. Tabl.2 shows the components of each function:

Table 2: Components of objective functions

Functions		
The amount of nitrogen dioxide produced in the supply chain (liters)	PN	**The function of environmental impacts**
Amount of carbon monoxide produced in the supply chain (liters)	PC	
The total cost of purchasing raw materials from suppliers	RC	**The function of Cost**
Fixed cost of open facilities	FC	
The variable cost of the open facility	VC	
Shipping costs	TC	
Missed sales cost	BC	

$$\boldsymbol{f_1} = \boldsymbol{FC} + \boldsymbol{VC} + \boldsymbol{TC} + \boldsymbol{RC} + \boldsymbol{BC} \tag{1}$$

$$\boldsymbol{FC} = \sum_{m} fc_m . x_m + \sum_{w} fc_w . x_w + \sum_{d} fc_d . x_d \tag{2}$$

$$\boldsymbol{VC} = \sum_{m} vc_m . dem_m + \sum_{w} vc_w . dem_w + \sum_{d} vc_d . dem_d \tag{3}$$

$$\begin{aligned} \boldsymbol{TC} = &\sum_{s}\sum_{m}\sum_{k} x_{sm}^{k} . c_{sm}^{k} .\ dis_{sm} \\ &+ \sum_{m}\sum_{w}\sum_{k} x_{mw}^{k} . c_{mw}^{k} .\ dis_{mw} \\ &+ \sum_{w}\sum_{d}\sum_{k} x_{wd}^{k} . c_{wd}^{tw} .\ dis_{wd} \\ &+ \sum_{d}\sum_{c}\sum_{k} x_{dc}^{k} . c_{dc}^{k} .\ dis_{dc} \end{aligned} \tag{4}$$

$$\boldsymbol{RC} = \sum_{s}\sum_{m} x_{sm} . cr_{sm} \tag{5}$$

$$\boldsymbol{BC} = \left[\sum_{c} dem_c - \sum_{d}\sum_{c}\sum_{td} x_{dc}^{k} \right] . p \tag{6}$$

$$\boldsymbol{f_2} = \boldsymbol{PN} + \boldsymbol{PC} \tag{7}$$

$$\boldsymbol{PN} = \begin{pmatrix} \sum_s \sum_m \sum_k x_{sm}^k . G_N^k .\ dis_{sm} + \\ \sum_m \sum_w \sum_k x_{mw}^k . G_N^k .\ dis_{mw} + \\ \sum_w \sum_d \sum_k x_{wd}^k . G_N^k .\ dis_{wd} + \\ \sum_d \sum_c \sum_k x_{dc}^k . G_N^k .\ dis_{dc} \end{pmatrix} \tag{8}$$

$$\boldsymbol{PC} = \begin{pmatrix} \sum_s \sum_m \sum_k x_{sm}^k . G_c^k .\ dis_{sm} + \\ \sum_m \sum_w \sum_k x_{mw}^k . G_c^k .\ dis_{mw} + \\ \sum_w \sum_d \sum_k x_{wd}^k . G_c^k .\ dis_{wd} + \\ \sum_d \sum_c \sum_k x_{dc}^k . G_c^k .\ dis_{dc} \end{pmatrix} \tag{9}$$

Eq. 1 represents the cost objective function that minimizes the total cost over the supply chain and includes the fixed cost of open facilities, the variable cost of open facilities, transportation costs, the cost of purchasing raw materials, and the cost of lost sales. Eq. 2 specifies the fixed cost of the supply chain based on open facilities. Eq. 3 calculates the variable cost based on the demand for each facility. Eq. 4 shows the shipping cost based on the distance and amount of products shipped by each vehicle. Eq. 5 calculates the cost of purchasing raw materials. Eq. 6 sets the penalty cost for unmet customer requests.

Eq. 7 shows the environmental objective function that seeks to reduce the number of hazardous gases produced, including nitrogen dioxide and carbon monoxide. Eq. 8 calculates the amount of nitrogen oxide emissions produced. The amount of nitrogen dioxide produced by each means of transport is based on the emission rate of nitrogen oxide and the distance traveled. Eq. 9 is similarly considered for carbon monoxide.

- **Constraints:**

$$\sum_k \sum_w x_{mw}^k = \sum_k \sum_s x_{sm}^k \qquad \forall m \tag{10}$$

$$\sum_k \sum_m x_{mw}^k = \sum_k \sum_d x_{wd}^k \qquad \forall w \tag{11}$$

$$\sum_k \sum_w x_{wd}^k = \sum_k \sum_c x_{dc}^k \qquad \forall d \tag{12}$$

$$\sum_k \sum_m x_{sm}^k \le ca_s . x_s \qquad \forall s \tag{13}$$

$$\sum_k \sum_w x_{mw}^k \le ca_m\ . x_m \qquad \forall m \tag{14}$$

$$\sum_k \sum_d x_{wd}^k \leq ca_w \,.\, x_w \qquad \forall w \tag{15}$$

$$\sum_k \sum_d x_{dc}^k \leq ca_d \,.\, x_d \qquad \forall d \tag{16}$$

$$x_s \leq \sum_k \sum_m x_{sm}^k \qquad \forall s \tag{17}$$

$$x_m \leq \sum_k \sum_w x_{mw}^k \qquad \forall m \tag{18}$$

$$x_w \leq \sum_k \sum_d x_{wd}^k \qquad \forall w \tag{19}$$

$$x_d \leq \sum_k \sum_c x_{dc}^k \qquad \forall d \tag{20}$$

$$\sum_d \sum_k x_{dc}^k \leq dem_c \qquad \forall c \tag{21}$$

$$\sum_s \sum_m x_{sm}^k \leq ca^k \qquad \forall k \tag{22}$$

$$\sum_m \sum_w x_{mw}^k \leq ca^k \qquad \forall k \tag{23}$$

$$\sum_w \sum_d x_{wd}^k \leq ca^k \qquad \forall k \tag{24}$$

$$\sum_d \sum_c x_{dc}^k \leq ca^k \qquad \forall k \tag{25}$$

Constraints Eq. 10 to Eq. 12 show the balance between supply chain facilities, meaning that, for example, for each producer, its total input is equal to its total output. Constraints Eq. 13 to Eq. 16 ensure that no more than the capacity of the facility can be claimed.

Constraints Eq. 17 to Eq. 20 also guarantee that if one facility does not provide any other facility at its low level, that facility will be closed and its binary variable will be zero. Constraint Eq. 21 shows that for each customer, the total amount of products transferred from the distribution centers to it can be less than the demand of that customer. Finally, Constraints Eq. 22 to Eq. 25 Average Transport Capacity Limits, which prevent shipping over the average capacity.

3.2 Method for solving the mathematical model of optimizing economic and environmental objective functions:

As noted, mathematical modeling was performed to optimize economic and environmental objective functions. The method of solving the model is using modeling in GAMS software.

3.2.1 Model assumptions:

- Customer demand is assumed to be constant. If their demand is not met, we face the cost of delayed order.
- Raw materials are of the same type and manufacturers supply them from different suppliers.

- Manufacturers, warehouses, distribution centers, and transportation options have limited capacity.
- Each of the suppliers can meet the demand of more than one manufacturer.
- Demand for each warehouse can be met by more than one manufacturer.
- The demand for each distribution center can be met by more than one warehouse.
- The demand of each customer can be met by more than one distribution center.
- The transportation options available for the facility are the same at different levels.
- Each transportation option has a default hazardous gas production rate.

3.2.2 Solving method

As mentioned earlier, the economic and environmental dimensions of the supply chain were optimized simultaneously and a set of answers was generated. Now it is time to add the social dimension and choose a final optimal answer from the previous set of answers. The social optimization method, modeled on the Versailles article (Schaltegger et al., 2014), will be a method based on consulting elites and experts. The method is that at first the appropriate criterion for measuring the state of stability is selected. Based on this criterion, 4 main categories of indicators, each of which includes several sub-indicators were selected as follows: (Bastian Buck et al., 2010) (Nikolaou et al., 2013).

Table 3: Selected indicators of measuring social sustainability - dimension related to employees

Employee and honorable work practices	
Employment	
LA1	Number and rate of employment of new employees and financial turnover of employees by age group, gender, and region
LA2	Full-time employee benefits
LA3	Parental leave and rate of return to work of eligible employees
Occupational safety and health	
LA4	Accidents at work
LA5	Joint Health and Safety Committees
LA6	Employees exposed to work-related illness
LA7	Occupational safety and health topics covered in formal agreements with trade unions
Education	
LA8	Educational per capita
LA9	Training programs and skills development
LA10	Performance appraisal and career development
Diversity and equal opportunities	
LA11	Combination of governance positions and labor force by gender, age group
Equal pay for women and men	
LA12	Basic wage ratio for women and men based on job class and region
Assessing suppliers for workforce practices	
LA13	Consider criteria for labor procedures to screen suppliers
LA14	Important implications for labor chain practices in the supply chain
Grievance Mechanisms about Labor Procedures	
LA15	Complaints received, addressed, and resolved regarding important implications related to labor practices in the organization's activities

Table 4: Selected indicators for measuring social sustainability - the dimension of rights

Human Right	
Investment	
HR1	Include human rights standards in investment contracts
HR2	The amount of staff training on human rights and related policies of the organization
Non-discrimination and meritocracy	
HR3	Events related to discrimination and lack of meritocracy
Freedom to form trade union groups and collective agreements	
HR4	Operations and suppliers whose risk of a breach is high and related support measures
Child labor	
HR5	Operations and suppliers in which the risk of violation is high and measures to abolish child labor
Forced or imposed labor	
HR6	Operations and suppliers for which the risk of a breach is high and measures to abolish forced labor
Security procedures	
HR7	How to train security forces about human rights and related policies of the organization
Indigenous rights	
HR8	incidents of violation of the rights of indigenous and local peoples
Operations evaluation	
HR9	Percentage of the organization's operations that have been evaluated in terms of human rights.
Assessing human rights in suppliers	
HR10	Consider human rights standards for screening suppliers
HR11	Important consequences of human rights violations in the supply chain
Mechanisms of human rights complaints	
HR12	Complaints received, addressed, and resolved regarding important consequences related to human rights violations in the activities of the organization

Table 5: Selected indicators for measuring social sustainability - community dimension

Society	
Local communities	
SO1	Participation of local communities
SO2	Evaluate the consequences and development plans in the organization's operations
Fight against corruption	
SO3	Informing and educating about anti-corruption practices and policies
SO4	Evaluate operations in terms of corruption-related risks
SO5	Corruption-related events
Public policy	
SO6	Financial and non-financial political gifts paid by the organization to governments and legal entities
Anti-competitive behavior	

SO7	Litigation related to anti-competitive and monopolistic behavior
Compliance with the rules	
SO8	Fines and penalties for non-compliance with relevant laws
Assessing suppliers for impacts on society	
SO9	Consider community-related criteria for screening suppliers
SO10	Important community-related implications for the supply chain
Grievance mechanisms about the effects on society	
SO11	Complaints received, addressed, and resolved regarding important community-related implications for the organization's activities

Table 6: Selected indicators of measuring social sustainability - the dimension of product responsibility

Product responsibility	
Consumer safety and health	
Status of safety and health assessment of products and services and incidents of non-compliance	PR1
Product labeling	
Information related to consumer safety and health in product labeling	PR2
Incidents of non-compliance with the rules	PR3
Customer satisfaction survey results	PR4
Marketing Communications	
Sale of banned or controversial products	PR5
Incidents of non-compliance with the rules	PR6
Consumer privacy	
Complaints related to the violation of consumer privacy or loss of customer information	PR7
Compliance with the rules	
Fines and penalties for non-compliance with relevant laws	PR8

The optimization method will be such that the status of each unit (including supplier, manufacturer, warehouse, and distributor) is measured in the introduced indicators. Experts are then asked to give each unit in each index a score between 9-0 (0 lowest and 9 highest). The average score of the sub-indicators will give the score of each indicator and the total score of the 4 main indicators will give the total score in the unit social criterion.

It should be noted that the optimal answer from the economic and environmental optimization was to determine which units (for example, S1 and S2 were selected from among the suppliers). Now move along the supply chain and the value of the social index for the selected units is calculated. The average score of the units will be the total social score for each chain. The chain with the highest social score is selected as the optimal answer.

3.2.3 Numerical example

To satisfy the market demand for the product in Asia and Australia, which has an average of 10 customers with specific demand, the company needs the participation of several manufacturing plants. It also involves selecting the right raw material suppliers for factories, as well as warehouses and distribution centers to store products and deliver them to end customers. The preliminary analysis identifies 7 different suppliers and 7 different manufacturers from different countries. Also, 5 warehouses and 4 distribution centers are scattered according to the map below. 3 different modes of transport communicate between facilities.

Figure 4: Scattering of identified facilities

The data generated related to fixed and variable costs of facilities, the capacity of facilities and means of transportation, pollution emission rates, transportation costs, penalty costs, etc. are as follows. (The logic of data production is random. Of course, in data production, it is noted that the chain is balanced and the model has an answer.)The data will be attached at the end of the article.

4. Results

The model was solved by entering the mathematical model and random data generated in GAMS software and selecting the CPLEX solution method. Each answer obtained consists of three important parts.

1. The optimal amount of objective functions in terms of their weight and importance.
2. The set of facilities selected (ie, for example, which supplier has been selected from among the suppliers. In fact, this part shows the selection or not of any facility that was shown in the model with a variable of zero or one).
3. Material flow path (ie, from which supplier to which manufacturer, by what means of transportation, and to what extent the material has been transferred).

4.1 Results of objective functions

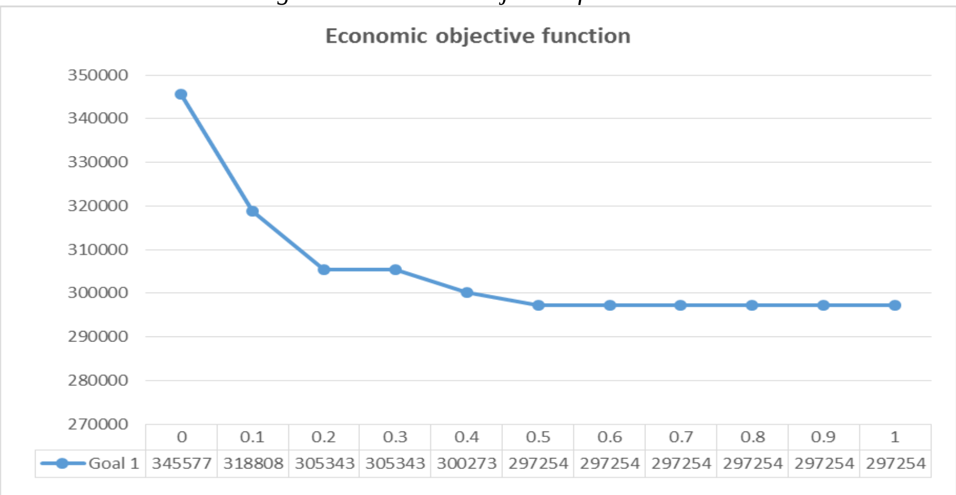
The results of solving the model were obtained by giving different weights to the economic and environmental objective functions as described in Tabl.7:

Table 7: The set of answers generated for the objective functions with GAMS

Objective 1:Eco	Objective 2:Env	Objective 1	Objective 2	Total Objective
0	1	345577	31489	31489
0.1	0.9	318808	32258	60913
0.2	0.8	305343	34998	89067
0.3	0.7	305343	34998	116102
0.4	0.6	300273	37896	142847
0.5	0.5	297254	40112	168683
0.6	0.4	297254	40112	194397
0.7	0.3	297254	40112	220111
0.8	0.2	297254	40112	245826
0.9	0.1	297254	40112	271540
1	0	297254	80224	297254

In the Tabl.7, Objective 1 is the value obtained for the economic objective function and Objective 2 is the value obtained for the environmental objective function, and the Objective column represents the weighted sum of these two functions. As mentioned in previous chapters, due to the importance of each of the two functions of economic and environmental Objectives, different weights were considered for them and the model was solved with these weights. In the following, we will examine how the weight of each function affects the value of the function and the optimal solution of the problem in the form of the following figures.

Figure 5: Economic objective function



As shown in Fig.5, the greater the weight and importance of the economic objective function (objective 1), the more optimized this function becomes, and the smaller the values. The environmental objective function behaves the same. When it has the highest importance (weight 1), it has the lowest (optimal) value. (Note Fig.6)

Figure 6: Environmental objective function

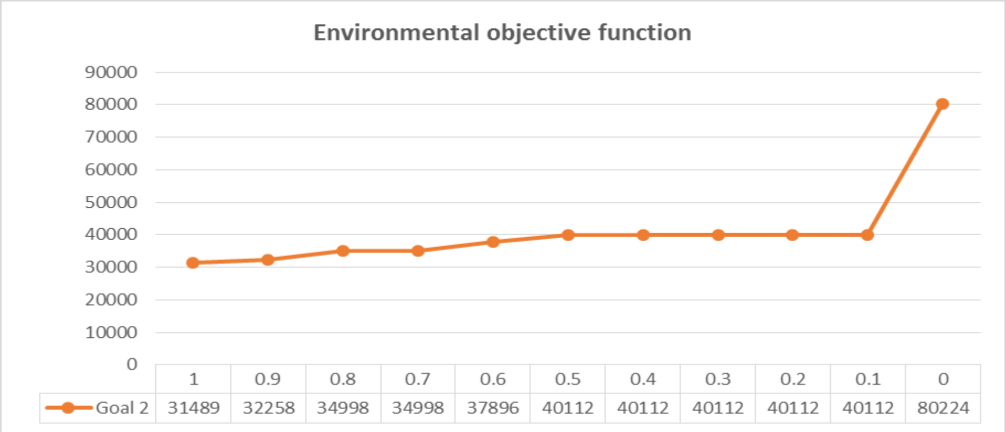
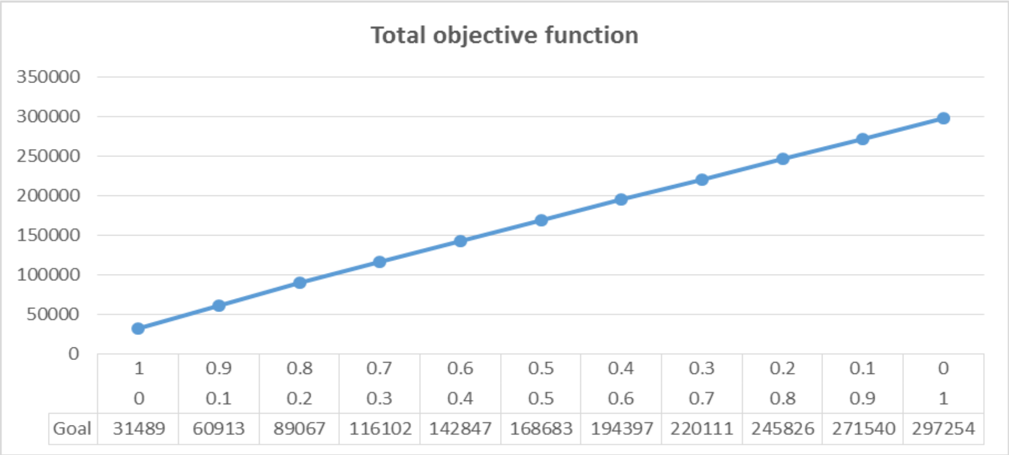


Figure 7: Total objective function (total weight of economic and environmental functions)



The total objective function is obtained from the weighted average of the economic and environmental objective functions. As you can see in Fig.7, this function has been increasing almost linearly. The reason for this is that as we move from left to right, the weight of the economic objective function increases, and the weight of the environmental objective function decreases. Since (due to random generation of data) the numerical value of the economic objective function is higher, the more weight of this function in total weight, the higher the value of the total objective function.

Figure 8: The trend of simultaneous changes of two economic and environmental functions and the weighted total objective function(Goal1 = objective1, Goal2 = objective2, Goal= Total objective)

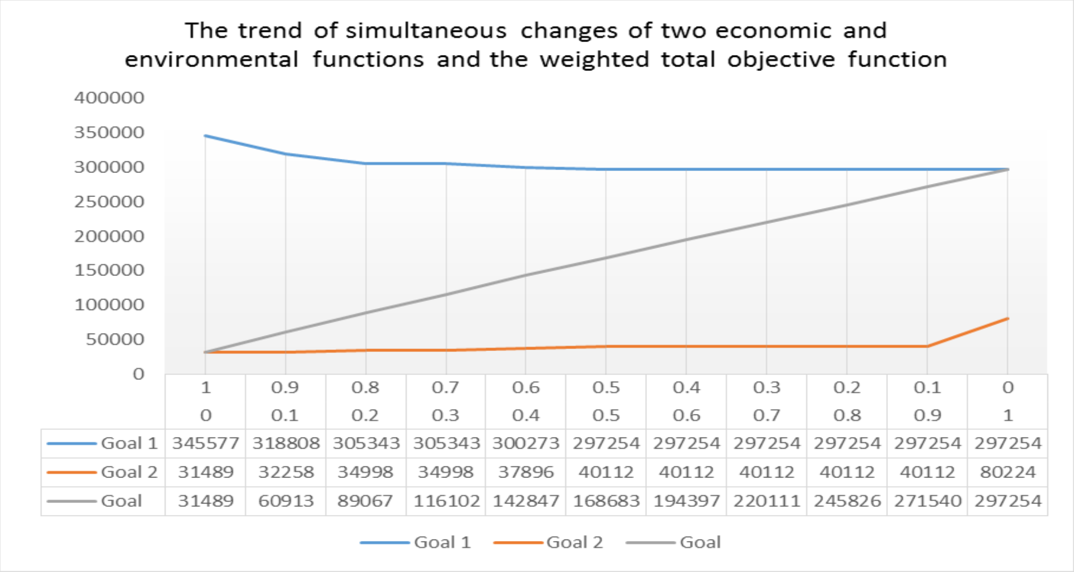


Fig.8 shows the trend of simultaneous changes of two economic and environmental functions and the objective function of the total weight. Of course, the important point in this section is that the value of the whole objective function (sum) is not a decision criterion here, and the purpose of weighting the functions is to achieve a set of answers. Obtained from this set and based on the social objective function, the final optimization will be done.

4.2 Results of the selected facility set

Selected facilities are facilities that have been selected to be in the optimal chain and in fact have a rate of 1 out of their set. Tabl.8 shows these facilities at each stage of the solution.

The numbers in columns S, M, W, D represent the number of facilities selected in the answer obtained. As can be seen, different facilities have been selected according to the importance of the economic objective function over the environmental objective function.

Table 8: Selected facility set

Sets	Objective1:Eco	Objective 2:Env	Objective 1	Objective 2	Total Objective	S	M	W	D
Set 1	0	1	345577	31489	31489	1,2,6	1,2,5	1,3,4	1,2,3,4
Set 2	0.1	0.9	318808	32258	60913	1,2	1,2	1,3	1,2,3
Set 3	0.2	0.8	305343	34998	89067	2,4	2,3	2,3	1,2,3
	0.3	0.7	305343	34998	116102	2,4	2,3	2,3	1,2,3
	0.4	0.6	300273	37896	142847	2,4	2,3	2,3	1,2,3
Set 4	0.5	0.5	297254	40112	168683	2,4,6	2,3,6	2,3,5	1,2,3,4
	0.6	0.4	297254	40112	194397	2,4,6	2,3,6	2,3,5	1,2,3,4
	0.7	0.3	297254	40112	220111	2,4,6	2,3,6	2,3,5	1,2,3,4
	0.8	0.2	297254	40112	245826	2,4,6	2,3,6	2,3,5	1,2,3,4
	0.9	0.1	297254	40112	271540	2,4,6	2,3,6	2,3,5	1,2,3,4
	1	0	297254	80224	297254	2,4,6	2,3,6	2,3,5	1,2,3,4

Examination of the set of answers (selected facilities S, M, W, D) The Tabl.8 shows that there are 4 sets of independent answers (4 categories of selected facilities). The method of selecting these sets is that first each unique answer is selected as a set of answers (such as sets 1 and 2 in the Tabl.8). From similar answers, the choice will be that their Objective 1 and Objective 2 values are compared.

By comparing these two values, one of the following conditions occurs. From one answer to another it is possible:

1- Objective 1 and Objective 2 both get worse.

2- Objective 1 and Objective 2 both get better.

3- Objective 1 gets better, but Objective 2 gets worse or vice versa.

If we deal with cases 1 and 2, we will choose the better answer (set 4). But in the third case, we will choose both answers (set 3). Because both functions are important to us and the final decision is based on the function of the third objective function, the social dimension of the problem. With these explanations, the selected answers in the Tabl.8 are specified. Thus, we have 5 optimal answers that must be made according to the social dimension of the final decision. Before examining how to choose the final answer, according to the social dimension, we will examine the amount of flow among the selected facilities, as the third part of the expected results.

4.3 Results of flow rate between selected facilities

Another important result for a full understanding of the supply chain is to know what flow of materials exists between the two facilities after selecting the optimal facility, and by which means of transport. Tabl.9 shows this flow.

Table 9: The amount of flow between the selected facilities

	From s to m	From m to w	From w to d	From d to c	
1	$x_{s1m1}^{k3}= 15285$ $x_{s2m2}^{k3}= 28120$ $x_{s6m5}^{k3}= 3485$	$x_{m1w1}^{k3} = 15285$ $x_{m2w3}^{k3} = 28120$ $x_{m5w4}^{k3} = 3485$	$x_{w1d1}^{k3} =15285$ $x_{w3d2}^{k3} = 13646$ $x_{w3d3}^{k3} = 14474$ $x_{w4d4}^{k3} = 3485$	$x_{d1c1}^{k3} = 4869$ $x_{d1c2}^{k3} = 5221$ $x_{d1c3}^{k3} = 5195$ $x_{d2c4}^{k3} = 4374$ $x_{d2c5}^{k3} = 4526$	$x_{d2c7}^{k3} = 4746$ $x_{d3c6}^{k3} = 4629$ $x_{d3c8}^{k3} = 4839$ $x_{d3c9}^{k3} = 5006$ $x_{d4c10}^{k3} = 3485$
2	$x_{s1m1}^{k3}= 15285$ $x_{s2m2}^{k3}= 31605$	$x_{m1w1}^{k3} = 15285$ $x_{m2w3}^{k3} = 31605$	$x_{w1d1}^{k3} =15285$ $x_{w3d2}^{k3} = 13646$ $x_{w3d3}^{k3} = 17959$	$x_{d1c1}^{k3} = 4869$ $x_{d1c2}^{k3} = 5221$ $x_{d1c3}^{k3} = 5195$ $x_{d2c4}^{k3} = 4374$ $x_{d2c5}^{k3} = 4526$	$x_{d2c7}^{k3} = 4746$ $x_{d3c6}^{k3} = 4629$ $x_{d3c8}^{k3} = 4839$ $x_{d3c9}^{k3} = 5006$ $x_{d4c10}^{k3} = 3485$
3	$x_{s2m2}^{k3}= 31605$ $x_{s4m3}^{k3}= 15285$	$x_{m2w3}^{k3} = 31605$ $x_{m3w2}^{k3} = 15285$	$x_{w2d1}^{k3} =15285$ $x_{w3d2}^{k3} = 13646$	$x_{d1c1}^{k3} = 4869$ $x_{d1c2}^{k3} = 5221$ $x_{d1c3}^{k3} = 5195$	$x_{d2c7}^{k3} = 4746$ $x_{d3c6}^{k3} = 4629$ $x_{d3c8}^{k3} = 4839$

	From s to m	From m to w	From w to d	From d to c
			$x^{k3}_{w3d3} = 17959$	$x^{k3}_{d2c4} = 4374$ $x^{k3}_{d3c9} = 5006$ $x^{k3}_{d2c5} = 4526$ $x^{k3}_{d4c10} = 348$
4	$x^{k3}_{s2m2} = 31605$ $x^{k3}_{s4m3} = 15285$	$x^{k3}_{m2w3} = 31605$ $x^{k3}_{m3w2} = 15285$	$x^{k3}_{w2d1} = 15285$ $x^{k3}_{w3d2} = 13646$ $x^{k3}_{w3d3} = 17959$	$x^{k3}_{d1c1} = 4869$ $x^{k3}_{d2c7} = 4746$ $x^{k3}_{d1c2} = 5221$ $x^{k3}_{d3c6} = 4629$ $x^{k3}_{d1c3} = 5195$ $x^{k3}_{d3c8} = 4839$ $x^{k3}_{d2c4} = 4374$ $x^{k3}_{d3c9} = 5006$ $x^{k3}_{d2c5} = 4526$ $x^{k3}_{d4c10} = 3485$
5	$x^{k3}_{s2m2} = 17959$ $x^{k3}_{s4m3} = 28931$	$x^{k3}_{m2w3} = 17959$ $x^{k3}_{m3w2} = 28931$	$x^{k3}_{w2d1} = 15285$ $x^{k3}_{w3d2} = 13646$ $x^{k3}_{w3d3} = 17959$	$x^{k3}_{d1c1} = 4869$ $x^{k3}_{d2c7} = 4746$ $x^{k3}_{d1c2} = 5221$ $x^{k3}_{d3c6} = 4629$ $x^{k3}_{d1c3} = 5195$ $x^{k3}_{d3c8} = 4839$ $x^{k3}_{d2c4} = 4374$ $x^{k3}_{d3c9} = 5006$ $x^{k3}_{d2c5} = 4526$ $x^{k3}_{d4c10} = 3485$
6	$x^{k3}_{s2m2} = 12953$ $x^{k3}_{s4m3} = 28931$ $x^{k3}_{s6m6} = 5006$	$x^{k3}_{m2w3} = 12953$ $x^{k3}_{m3w2} = 28931$ $x^{k3}_{m6w5} = 5006$	$x^{k3}_{w2d1} = 15285$ $x^{k3}_{w2d2} = 13646$ $x^{k3}_{w3d3} = 12953$ $x^{k3}_{w5d4} = 5006$	$x^{k3}_{d1c1} = 4869$ $x^{k3}_{d2c7} = 4746$ $x^{k3}_{d1c2} = 5221$ $x^{k3}_{d3c6} = 4629$ $x^{k3}_{d1c3} = 5195$ $x^{k3}_{d3c8} = 4839$ $x^{k3}_{d2c4} = 4374$ $x^{k3}_{d3c10} = 3485$ $x^{k3}_{d2c5} = 4526$ $x^{k3}_{d4c9} = 5006$
7	“	“	“	“
8	“	“	“	“
9	“	“	“	“
10	“	“	“	“
11	“	“	“	“

Due to the random production of data, it is not possible to give a general interpretation of the reason for the choice of vehicles and the amount of flow. It can only be noted that the logic of optimization is to minimize economic and environmental functions throughout the chain and to be minimal between the two facilitations does not necessarily mean choosing that path.

Now it is time to add a social dimension and choose a final optimal answer from the set of answers. Each unit in each index is rated between 9-0 (0 lowest and 9 highest).

Table 10: Total social index

The main index	Index	D1	Index value	Total social index
"Employee and Honorable Work Procedures" indexes	LA1	8	4.47	17.3
	LA2	1		
	LA3	9		
	LA4	2		
	LA5	0		
	LA6	4		
	LA7	7		
	LA8	6		
	LA9	6		
	LA10	2		
	LA11	6		
	LA12	1		
	LA13	5		
	LA14	3		
	LA15	7		
"Human Right" indexes	HR1	4	4.5	
	HR2	5		
	HR3	4		
	HR4	7		
	HR5	2		
	HR6	1		
	HR7	1		
	HR8	9		
	HR9	3		
	HR10	7		
	HR11	8		
	HR12	3		
"Society" indexes	SO1	7	5.2	
	SO2	9		
	SO3	8		
	SO4	0		
	SO5	9		
	SO6	3		
	SO7	3		
	SO8	6		
	SO9	6		
	SO10	4		
	SO11	2		
"Product Responsibility" indexes	PR1	0	3.1	
	PR2	4		
	PR3	5		
	PR4	1		
	PR5	9		
	PR6	5		
	PR7	1		
	PR8	0		

The main index	Index	M1	Index value	Total social index
"Employee and Honorable Work Procedures" indexes	LA1	3	3.37	19.03
	LA2	4		
	LA3	2		
	LA4	1		
	LA5	2		
	LA6	1		
	LA7	8		
	LA8	2		
	LA9	4		
	LA10	3		
	LA11	2		
	LA12	5		
	LA13	6		
	LA14	5		
	LA15	8		
"Human Right" indexes	HR1	4	5.7	
	HR2	8		
	HR3	7		
	HR4	6		
	HR5	0		
	HR6	9		
	HR7	1		
	HR8	8		
	HR9	7		
	HR10	4		
	HR11	5		
	HR12	9		
"Society" indexes	SO1	8	4.0	
	SO2	3		
	SO3	3		
	SO4	5		
	SO5	3		
	SO6	1		
	SO7	6		
	SO8	1		
	SO9	7		
	SO10	2		
	SO11	5		
"Product Responsibility" indexes	PR1	3	5.6	
	PR2	5		
	PR3	8		
	PR4	3		
	PR5	6		
	PR6	7		
	PR7	8		
	PR8	5		

Social points have been calculated for the other units. Finally, the average social score of all selected units is obtained according to the Tabl.11 .

Table 11: Total social score

Sets	Objective1 :Eco	Objective 2 :Env	Objective 1	Objective 2	Total Objective	S	M	W	D	Total social score
Set 1	0	1	345577	31489	31489	1,2,6	1,2,5	1,3,4	1,2,3,4	17.19
Set 2	0.1	0.9	318808	32258	60913	1,2	1,2	1,3	1,2,3	17.56
Set 3	0.2	0.8	305343	34998	89067	2,4	2,3	2,3	1,2,3	16.75
	0.4	0.6	300273	37896	142847	2,4	2,3	2,3	1,2,3	16.75
Set 4	0.5	0.5	297254	40112	168683	2,4,6	2,3,6	2,3,5	1,2,3,4	16.83

Set 2 is obtained as the optimal answer.

5. Conclusion

In this study, we sought to provide a sustainable model for the supply chain management. A model that considers all three dimensions of sustainability, namely economic, environmental, and social. To address the issue and examine the evolution of the supply chain to achieve sustainability, we first discussed how the supply chain and its types emerged. Then it was pointed out that with the complexity of supply chains and the difficulty of coordinating the flow of materials, information, and finance with scientific and integrated management of the supply chain, a competitive advantage can be achieved. With such an attitude, the supply chain management approach emerged and various factors such as increasing the level of outsourcing, increasing transportation costs, competitive pressures, and globalization, led organizations to better manage their supply chain. Over time, paradigm and perspective problems led to changing attitudes in supply chain management. Problems such as environmental pollution, global warming, and rising carbon levels have necessitated the evaluation and selection of technologies to reduce the harmful effects of the environment. The desire of customers, the pressure of nature-friendly groups, international and government organizations that support the environment caused organizations to pay attention to issues related to environmental management and energy. To solve these problems, green supply chain management was introduced to minimize waste and emitting pollutants along the supply chain. But the evolution of supply chain management did not end there, and attention to the third dimension of sustainability, namely social sustainability, set a new path for researchers. Many researchers have tried to implement social standards and guidelines in supply chain management and integrate three dimensions of sustainability in this area and formed a new topic called sustainable supply chain management. Examining the literature of green supply chain and sustainable supply chain, it is observed that there is no single definition of these concepts in the literature. The lack of a precise definition and the many similarities between the existing definitions and the overlap of the concepts have caused these two concepts to be used instead of each other. Generally, in the supply chain literature, more research has been done on two dimensions of sustainability (either economic and environmental or economic and social). Articles dealing with all three aspects of sustainability require little research. Also, in such articles, a small number have done mathematical modeling and there are gaps in this field of literature.

Articles that examine the social aspects of the supply chain, due to the wide range of social issues and the lack of a single approach, usually follow one or more indicators (eg job creation) along the chain and suggest ways to improve in that area. In this paper, after a general statement of the problem, which was the allocation of equipment and transportation options in a five-tier supply chain, the problem assumptions are described, and then the mathematical model for optimizing economic and environmental objective functions is presented. Then, the solution method, Gomez software, was introduced, and finally, the model solution method was selected from among the various solution methods that existed in the software to solve complex integer programming problems. Up to this point in our research, we have dealt with two dimensions of sustainability. But in this section, the third dimension, namely the social dimension, and the usual methods for examining it in organizations were stated. Finally, our method for selecting the optimal answer based on the social approach is explained. To show the efficiency of the proposed mathematical model and our optimization methods and the process of achieving an optimal and stable solution to the problem concerning the stability dimensions, a numerical example was provided whose data were generated randomly. By placing these values in the model and using solution methods, the results are presented in tables.

The presented results show that the mathematical model is applied and can be used for real problems and give optimal answers.

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