ISSN: 2037-4445

Designing a Green Supply Chain Model (Case Study: Behnoor Safety Glass Production Company)

Mohsen Kheirabadi[a], Adel Azar[b], Gholamreza Goudarzi[c]

[a] Faculty of Management and Economics, Tarbiat Modares University, Tehran, Iran

[b] Faculty of Management and Economics, Tarbiat Modares University, Tehran, Iran

[c] Faculty of Islamic Studies and Management, Imam Sadeq University, Tehran, Iran

Abstract

In the current competitive environment, an efficient and effective supply chain is considered a sustainable competitive advantage for companies that can guarantee the survival of companies and sustainable export of companies in the market. The product distribution from the origin point to the consumption point is one of the significant parts of the gross national product, which reveals how much wealth a country spends. In parallel with these growths in the economic environment, anxieties about environmental and social factors have caused countries to pay special attention to the green supply chain and reverse logistics to reduce the harmful environmental-social effects and reuse of consumed goods to save energy. In the current research, we have tried to design the goal planning model of green supply chain management, and considering the basic limitations that include market limitations, technical limitations, inventory, and government and institution policies, this process will be optimized. In this research, with a comprehensive review of the literature, green criteria in the selection of suppliers and distributors were extracted at three high, intermediate, and operational levels and then prioritized using network analysis techniques. The goal model designed in this research was solved using collecting information from the supply chain management team of the company “Behnoor Safety Glass” and the optimal answers were obtained. Via comparing the results obtained from solving the deterministic and fuzzy goal model with real data, it is possible to understand the efficiency of the model in reducing raw material consumption, carbon dioxide production, and transportation costs.

Keywords: Green supply chain management, Goal planning, Fuzzy Goal planning, Analytic Network Process (ANP)

Introduction

The green chain that we are considering currently was offered by the European Union at the beginning of the 21st century. Numerous small and medium-sized companies have created collaborations with their supply chain partners hoping they can engage in environmental management and green redesign of their products. (Chiou, 2007) The green supply chain has a rich literature on the subject. Sirvastava (2007) and Cohen et al. (1989) state that green activities in the supply chain comprise product design, purchase of raw materials, production process, final product delivery, waste, and end-of-life management. Sirvastava has done an all-encompassing review on this topic and has addressed two issues: a green design for products and green operations. Reverse logistics, network design, and waste management are debates related to this concept. Investing in equipment that decreases environmental pollution is one of the other aspects of interest.

Kannan et al. (2009) presented an integrated model that inspected and selected suppliers based on their environmental performance using the structural-conceptual model and hierarchical analysis. Chan (2007) recognized the effective drivers in the green supply chain using the structural-conceptual model. Shekari (2004) identified, formulated and prioritized the components of green productivity with the approach of green supply chain management using the Multi-Attribute Decision Making (MADM) technique. Kannan, Sasikumar, and Devika (2010) developed a multi-level, multi-period, multi-product closed-loop supply chain network model for returned products and deciding on procurement, production, distribution, recycling, and waste. In this article, heuristic genetic algorithms and integer linear programming are used. Yuzhong (2008) offered a model of a closed-loop supply chain network that comprises raw material suppliers, manufacturers, retailers, customers, and recycling centers. This paper presents different cases to show the effect of product return rate, raw material shipping rate, and recyclable product shipping rate on the balance between net income and transportation.

Lately, much research has been done on multi-objective supply chain design. For instance, multi-objective planning has been proposed by Liu (2007) to investigate solid waste management. Humphreys (2003) offered a framework of multi-objective modeling that could concurrently provide the two goals of reducing costs and increasing customer satisfaction. However, no model considers environmental issues distinctly. Guinee (2002) presented a model for the simultaneous optimization of logistics and products used in reverse logistics in a closed-loop supply chain. Amy (2009) conducted multi-objective planning to recognize the location and capacity of hazardous materials incineration equipment and balance it with social, economic, and environmental impacts. Another study was done by Paksari et al. (2010), which considered the green effect on the closed-loop supply chain network and tried to avert the entry of carbon dioxide or CO_2 polluting gases into the air and inspire customers to use recyclable materials.

The necessity to implement environmental considerations in the glass industry is seen more than in other industries. Some unavoidable pollution in glass production processes makes green thinking turn to another side of this industry, which is to clean the entire chain from the extraction of raw materials to the final consumer. These activities make the critics look at the various pollutions of this industry with a more favorable view. Cleaning the supply chain is the minimum thing that can be done to decrease inevitable pollution, such as the greenhouse effect, high energy consumption, and air pollutants from the glass industry (Kheirabadi, Azar, Shahrouzi, 2012).

Via studying the literature, this gap is felt that there is no integrated model that proposes and examines the process of selecting suppliers, production processes, transportation, and recycled materials with a green approach. In this research, we aim to quantify the environmental criteria as much as possible and use them by presenting a multi-objective problem for designing the supply chain network in optimizing production lines and increasing environmental compatibility.

Method

The research method in the present research is the method of management science (MS) in which we design a model. It is not possible to envisage a statistical population for it. Somewhat, this research is a type of case study, the case study of which is the “Behnoor Safety Glass” manufacturing company. Based on the recommendation of the experts in the production process, among the numerous products of the company, the windshield was selected for one year.

The data needed collected to design the model comes from three sources: interviews with managers and experts in purchasing, production, production planning, sales and administration, review and study of factory documents, including the company's certificate, product list, raw material list, etc. structured purchasing, production and sales procedures.

Analysis of the written model at the strategic level with a soft modeling approach was done using Super Decision software, and at the operational level with a hard modeling approach, using Excel and Lingo 13 software, which can solve linear and non-linear programming models.

In the present research, the general procedure of modeling is that after determining the time and place of the research, the data required for the design of the model will be collected from the existing literature. The general modeling procedure is shown in Figure (1).

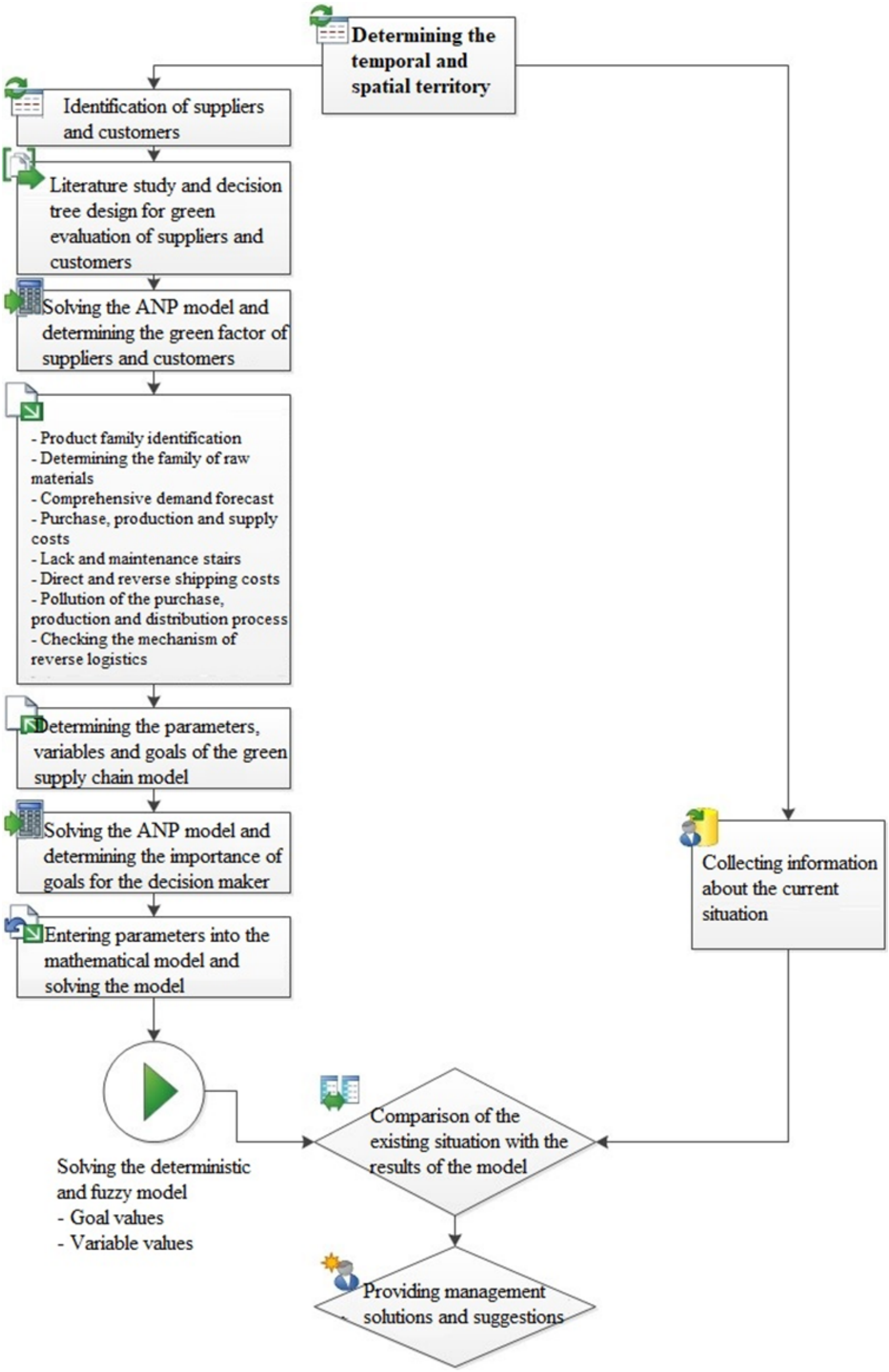

Figure 1: Overall modeling procedure

Designing mathematical models of different levels of the supply chain

Strategic level model

At this stage, through the Analytical Network Process (ANP), suppliers and customers will be compared and ranked in terms of attention to environmental criteria.

Evaluating the organizational structure of suppliers and customers from the point of view of complying with environmental issues in their work by studying and reviewing the research literature in green supplier and customer selection and interviewing experts and examining their opinions in choosing the most important criteria of the decision-making network was depicted as Figure (2).

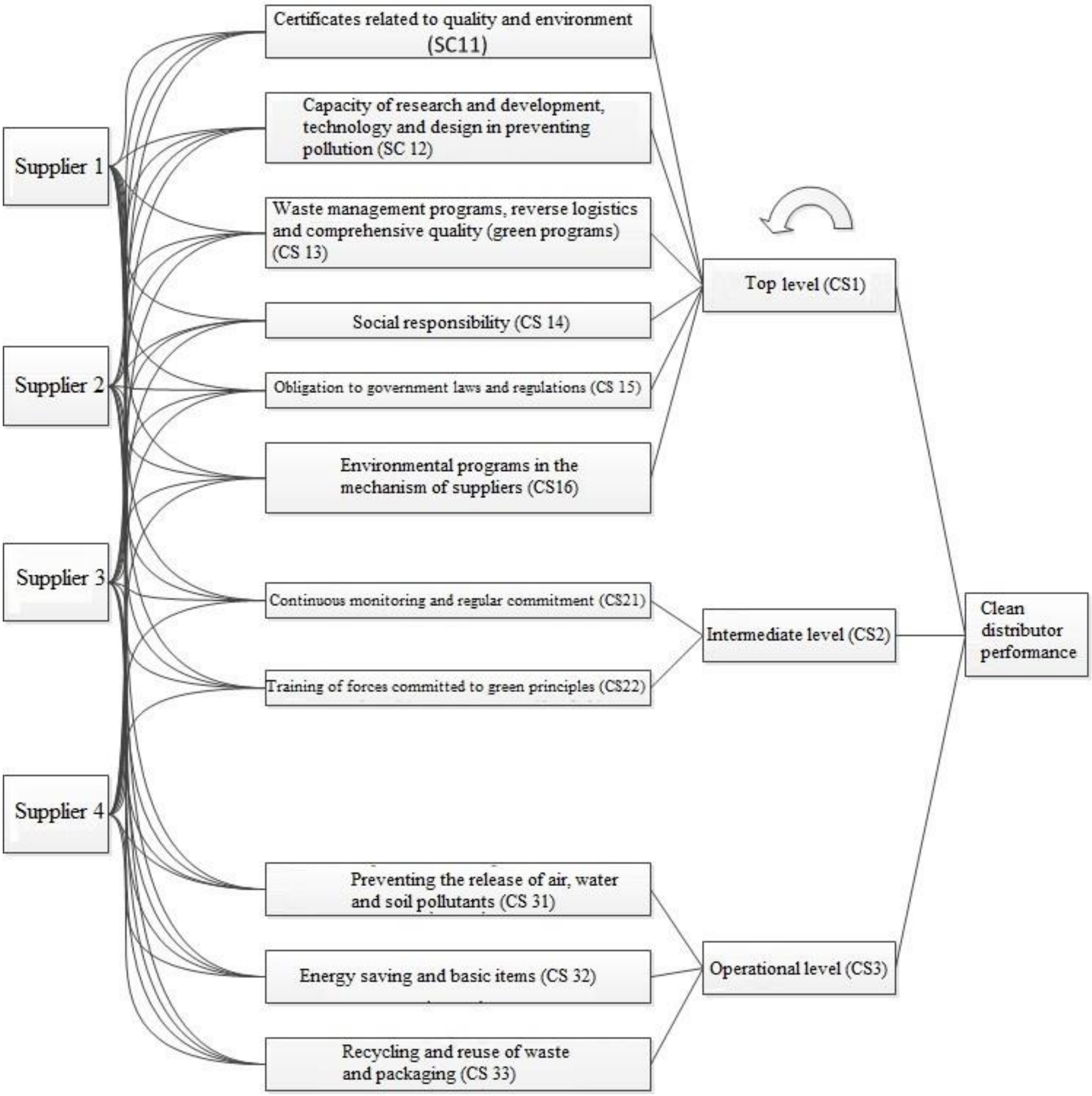

Figure 2: Decision-making network

The decision-making network for choosing green customers has also been drawn, as in Figure (2, with the difference that the customers have been evaluated.

Operational level model

The model designed in this research comprises operational-level decisions. The model used at this level is a linear goal model. The aim of planning at this level is to attain comprehensive planning of purchase, production, and distribution, based on which one year can be planned.

Model design assumptions:

1. Each customer's demand is specific and must be met
2. Flow of materials and products may be conducted only sequentially

3. Capacity of all components is specific and limited

Operational model goals

$$\min Cost_1 = \sum_i \sum_r \sum_t X_{rt}^{i} \times H_t^i + \sum_k \sum_t Y_t^{k} \times H_t^k + \sum_k \sum_t Z_t^k \times H_t^k + \sum_w \sum_t Z_t^w \times H_{wt}$$

$$\min Cost_2 = \sum_m \sum_k K^{km} \times C^{km} + \sum_m T^{m} \times C^{m} + \sum_u \sum_w O^w \times C^{uw} + \sum_p \sum_m S^{mp} \times C^{mp}$$
$$+ \sum_p D^p \times C^p + \sum_z \sum_p F^{pz} \times C^{pz} + \sum_i \sum_z G^{zi} \times C^{zi}$$

$$\min CO_2 = (\sum_i \sum_r \sum_t X_{rt}^{i} \times CO_2^{it} + \sum_k \sum_t Y_t^{k} \times CO_2^{kt} + \sum_w \sum_k \sum_t Z_t^{wk} \times CO_2^{twk} + \sum_t Z_t^w \times CO_2^{tw}$$
$$+ \sum_k (De^k - E_k + EI) \times CO_2^p) + (\sum_k \sum_m K^{km} \times CO_2^{km}$$
$$+ \sum_m T^m \times CO_2^m + \sum_w \sum_t O^w \times CO_2^{tw} + \sum_p \sum_m S^{mp} \times CO_2^{mp}$$
$$+ \sum_p D^p \times CO_2^p + \sum_p \sum_z F^{pz} \times CO_2^{pz} + \sum_i \sum_z G^{zi} \times CO_2^{zi})$$

$$\min Purchase = \sum_i \sum_r A_r^i \times P_r^i - (\sum_w O^w \times P + \sum_i \sum_z G^{zi} \times P^i)$$

$$\min Warehouse = \sum_k CS^k \times E_k + \sum_w \sum_r K_r^w \times EI_r + \sum_w EI \times K^w$$

$$\max Utility = \sum_i WS_i \times X_{rt}^{i} + \sum_k WD_k \times (Y_t^{k} + Z_t^k)$$

Green supply chain deterministic goal planning operational model (GPGrSCM)

$$\text{MinZ} = \text{U}_1\text{D}_1^+ + \text{U}_2\text{D}_2^+ + \text{U}_3\text{D}_3^+ + \text{U}_4\text{D}_4^+ + \text{U}_5\text{D}_5^+ + \text{U}_6\text{D}_6^-$$

Subject to:

$$[Goal\,1] \quad \sum_i \sum_r \sum_t X_{rt}^{i} \times H_t^i + \sum_k \sum_t Y_t^{k} \times H_t^k + \sum_k \sum_t Z_t^k \times H_t^k + \sum_w \sum_t Z_t^w \times H_{wt} - D_1^+ \le G_1$$

$$[Goal\,2] \quad \sum_m \sum_k K^{km} \times C^{km} + \sum_m T^m \times C^m + \sum_k U^k \times C^k + \sum_u \sum_w O^w \times C^{uw} + \sum_p \sum_m S^{mp} \times C^{mp}$$
$$+ \sum_p D^p \times C^p + \sum_z \sum_p F^{pz} \times C^{pz} + \sum_i \sum_z G^{zi} \times C^{zi} - D_2^+ \le G_2$$

$$[Goal\,3]\quad (\sum_i\sum_r\sum_t X_{rt}^{\,i}\times CO_2^{it}+\sum_k\sum_t Y_t^{\,k}\times CO_2^{kt}+\sum_w\sum_k\sum_t Z_t^{wk}\times CO_2^{twk}+\sum_t Z_t^{w}\times CO_2^{tw}$$
$$+\sum_k (De^k - E_k + EI)\times CO_2^{p})+(\sum_k\sum_m K^{km}\times CO_2^{km}$$
$$+\sum_m T^{m}\times CO_2^{m}+\sum_w\sum_t O^{w}\times CO_2^{tw}+\sum_p\sum_m S^{mp}\times CO_2^{mp}$$
$$+\sum_p D^{p}\times CO_2^{p}+\sum_p\sum_z F^{pz}\times CO_2^{pz}+\sum_i\sum_z G^{zi}\times CO_2^{zi})-D_3^{+}\le G_3$$

$$[Goal\,4]\quad \sum_i\sum_r A_r^{i}\times P_r^{i}-(\sum_w O^{w}\times P+\sum_i\sum_z G^{zi}\times P^{i})-D_4^{+}\le G_4$$

$$[Goal\,5]\quad \sum_k CS^{k}\times E_k+\sum_w\sum_r K_r^{w}\times EI_r+\sum_w EI\times K^{w}-D_5^{+}\le G_5$$

$$[Goal\,6]\quad \sum_i WS_i\times X_{rt}^{\,i}+\sum_k WD_k\times(Y_t^{\,k}+Z_t^{\,k})+D_6^{-}\ge G_6$$

$$[1]\quad A_i^{r}\le Ca_r^{i}\qquad \forall_{i,r}$$

$$[2]\quad G\le Ca$$

$$[3]\quad \sum_i\sum_t X_{rt}^{\,i}\le Ca_r^{w}\qquad \forall_{r,w}$$

$$[4]\quad T^{m}+S^{mp}\le Ca^{m}\qquad \forall_{m}$$

$$[5]\quad \sum_w O^{w}\le Ca^{u}\qquad \forall_{u}$$

$$[6]\quad D^{p}+\sum_z F^{pz}\le Ca^{p}\qquad \forall_{p}$$

$$[7]\quad \sum_i G^{zi}\le Ca_r^{z}\qquad \forall_{r,z}$$

$$[8]\quad \sum_i\sum_t X_{rt}^{\,i}\le Ca_t^{i}\qquad \forall_{t,i}$$

$$[9]\quad \sum_k Y_t^{\,k}+Z_t^{\,k}\le Ca_t\qquad \forall_{t}$$

$$[10]\quad \sum_t X_{rt}^{\,i}=A_r^{i}\qquad \forall_{r,i}$$

$$[11]\quad \sum_k\sum_w\sum_t Z_t^{wk}\le\sum_w\sum_t Z_t^{w}+\sum_w O^{w}-EI$$

$$[12]\quad \sum_t Y_t^{\,k}+\sum_w\sum_t Z_t^{wk}+E_k=De^{k}\qquad \forall_{k}$$

$$[13]\quad lbk\le\sum_m k^{km}\le ubk)\qquad \forall_{k}$$

ISSN: 2037-4445

[14] $\beta(\sum_{k} k^{km}) = T^{m} \qquad \forall_{m}$

[15] $(1-\beta)(\sum_{k} k^{km}) = \sum_{p} S^{mp} \qquad \forall_{m}$

[16] $\chi(\sum_{m} T^{m}) = \sum_{w} O^{w}$

[17] $\delta(\sum_{m} S^{mp}) = D^{p} \qquad \forall_{p}$

[18] $(1-\delta)(\sum_{m} S^{mp}) = \sum_{z} F^{pz} \qquad \forall_{p}$

[19] $\varepsilon(\sum_{p} F^{pz}) = \sum_{i} G^{zi} \qquad \forall_{z,i}$

[20] $\sum_{i} A_{r}^{i} \geq US_{r} \times G + EI_{r} \qquad \forall r$

[21] $G = EI + \sum_{k}\sum_{t} Y_{t}^{k} + \sum_{w}\sum_{k}\sum_{t} Z_{t}^{wk}$

$$G, X_{r,t}^{i}, Y_{t}^{k}, Z_{t}^{w}, Z_{t}^{wk}, A_{r}^{i}, E_{k}, K^{km}, T^{m}, O^{w}, S^{\partial mp}, D^{p}, F^{pz}, G^{zi} \geq 0$$

Green supply chain fuzzy goal planning operational model (FGPGrSCM)

$$\max Z = \lambda$$

Subject to:

$$U_1 D_1^{+} + U_2 D_2^{+} + U_3 D_3^{+} + U_4 D_4^{+} + U_5 D_5^{+} + U_6 D_6^{-} + \lambda(Z_1 - Z_0) \leq Z_1$$

[Goal 1] $\sum_{i}\sum_{r}\sum_{t} X_{rt}^{i} \times H_{t}^{i} + \sum_{k}\sum_{t} Y_{t}^{k} \times H_{t}^{k} + \sum_{k}\sum_{t} Z_{t}^{k} \times H_{t}^{k} + \sum_{w}\sum_{t} Z_{t}^{w} \times H_{wt} - D_1^{+} \leq G_1$

[Goal 2] $\sum_{m}\sum_{k} K^{km} \times C^{km} + \sum_{m} T^{m} \times C^{m} + \sum_{k} U^{k} \times C^{k} + \sum_{u}\sum_{w} O^{w} \times C^{uw} + \sum_{p}\sum_{m} S^{mp} \times C^{mp}$
$+ \sum_{p} D^{p} \times C^{p} + \sum_{z}\sum_{p} F^{pz} \times C^{pz} + \sum_{i}\sum_{z} G^{zi} \times C^{zi} - D_2^{+} \leq G_2$

[Goal 3] $(\sum_{i}\sum_{r}\sum_{t} X_{rt}^{i} \times CO_2^{it} + \sum_{k}\sum_{t} Y_{t}^{k} \times CO_2^{kt} + \sum_{w}\sum_{k}\sum_{t} Z_{t}^{wk} \times CO_2^{twk} + \sum_{t} Z_{t}^{w} \times CO_2^{tw}$
$+ \sum_{k} (De^{k} - E_{k} + EI) \times CO_2^{p}) + (\sum_{k}\sum_{m} K^{km} \times CO_2^{km}$
$+ \sum_{m} T^{m} \times CO_2^{m} + \sum_{w}\sum_{t} O^{w} \times CO_2^{tw} + \sum_{p}\sum_{m} S^{mp} \times CO_2^{mp}$
$+ \sum_{p} D^{p} \times CO_2^{p} + \sum_{p}\sum_{z} F^{pz} \times CO_2^{pz} + \sum_{i}\sum_{z} G^{zi} \times CO_2^{zi}) - D_3^{+} \leq G_3$

[Goal 4] $\sum_{i}\sum_{r} A_{r}^{i} \times P_{r}^{i} - (\sum_{w} O^{w} \times P + \sum_{i}\sum_{z} G^{zi} \times P^{i}) - D_4^{+} \leq G_4$

[Goal 5] $\sum_{k} CS^{k} \times E_{k} + \sum_{w}\sum_{r} K_{r}^{w} \times EI_{r} + \sum_{w} EI \times K^{w} - D_5^{+} \leq G_5$

ISSN: 2037-4445

$$[Goal\,6]\quad \sum_i WS_i \times X_{rt}^{\,i} + \sum_k WD_k \times (Y_t^{\,k} + Z_t^{\,k}) + D_6^- \geq G_6$$

$$[1]\quad A_i^r \leq Ca_r^i \qquad \forall_{i,r}$$

$$[2]\quad G \leq Ca$$

$$[3]\quad \sum_i \sum_t X_{rt}^{\,i} \leq Ca_r^w \qquad \forall_{r,w}$$

$$[4]\quad T^{\,m} + S^{\,mp} \leq Ca^m \qquad \forall_m$$

$$[5]\quad \sum_w O^w \leq Ca^u \qquad \forall_u$$

$$[6]\quad D^{\,p} + \sum_z F^{\,pz} \leq Ca^p \qquad \forall_p$$

$$[7]\quad \sum_i G^{\,zi} \leq Ca_r^z \qquad \forall_{r,z}$$

$$[8]\quad \sum_i \sum_t X_{rt}^{\,i} \leq Ca_t^i \qquad \forall_{t,i}$$

$$[9]\quad \sum_k Y_t^{\,k} + Z_t^{\,k} \leq Ca_t \qquad \forall_t$$

$$[10]\quad \sum_t X_{rt}^{\,i} = A_r^i \quad \forall_{r,i}$$

$$[11]\quad \sum_k \sum_w \sum_t Z_t^{wk} \leq \sum_w \sum_t Z_t^{w} + \sum_w O^w - EI$$

$$[12]\quad \sum_t Y_t^{\,k} + \sum_w \sum_t Z_t^{wk} + E_k = De^k \qquad \forall_k$$

$$[14]\quad lbk - P_k^l \leq \sum_m k^{\,km} - P_k^l \lambda \quad \forall_k$$

$$[15]\quad \sum_m k^{\,km} + P_k^u \lambda \leq ubk + P_k^u \quad \forall_k$$

$$[16]\quad \beta(\sum_k k^{\,km}) = T^{\,m} \qquad \forall_m$$

$$[17]\quad (1-\beta)(\sum_k k^{\,km}) = \sum_p S^{\,mp} \qquad \forall_m$$

$$[18]\quad \chi(\sum_m T^{\,m}) = \sum_w O^w$$

$$[19]\quad \delta(\sum_m S^{\,mp}) = D^{\,p} \qquad \forall_p$$

$$[20]\quad (1-\delta)(\sum_m S^{\,mp}) = \sum_z F^{\,pz} \qquad \forall_p$$

$$[21]\quad \varepsilon(\sum_p F^{\,pz}) = \sum_i G^{\,zi} \qquad \forall_{z,i}$$

$$[22] \quad \sum_i A_r^i \geq US_r \times G + EI_r \qquad \forall r$$

$$[23] \quad G = EI + \sum_k \sum_t Y_t^{\,k} + \sum_w \sum_k \sum_t Z_t^{wk}$$

$$G, X_{r,t}^{\,i}, Y_t^{\,k}, Z_t^w, Z_t^{wk}, A_r^i, E_k, K^{km}, T^{\,m}, O^w, S^{\partial mp}, D^{\,p}, F^{\,pz}, G^{zi}, \lambda \geq 0$$

Findings

Solving the strategic level model

At this level, using the ANP technique, suppliers of raw materials and customers are evaluated and finally, the score of each of them is determined.

Table 1: Name and product code of each supplier

Supplier code (i)	Raw material family (r)
1	Flute glass 1
2	Flute glass 2
3	Flute glass 3
4	Flute glass 4
5	Polymer film 1
6	Polymer film 2
7	Polymer film 3
8	Silver glue
9	Mirror base 1
10	Mirror base 2
11	Glue 1
12	Glue 2
13	T-connection 1
14	T-connection 2
15	Tin
16	Tin

Among these raw materials, only the amount and price of 8 primary raw materials are important, which are included in the analysis.

Table 2: Customer name and code

Customer code	Customer Name
1	Car manufacturer (1)
2	Car manufacturer (2)

Customer code	Customer Name
3	Car manufacturer (3)
4	Spare parts

The calculated weights for the main criteria, sub-criteria, and finally the weight of each supplier and customer are listed in the following tables.

Table 3: Weight of suppliers by ANP method

	Operational level			Middle level		Top-level						Main criteria
	0.506			0.131		0.362						
Final score	3	2	1	2	1	6	5	4	3	2	1	Sub-criteria
	0.09	0.818	0.09	0.125	0.875	0.026	0.045	0.068	0.565	0.233	0.06	
0.528	Supplier 1											
0.307	Supplier 2											
0.111	Supplier 3											
0.05	Supplier 4											
0.33	Supplier 5											
0.33	Supplier 6											
0.33	Supplier 7											
1	Supplier 8											

Table 4: Weight of customers by ANP method

Customer Name	Final score
Car manufacturer (1)	0.304
Car manufacturer (2)	0.304
Car manufacturer (3)	0.304
Spare parts (4)	0.088

Implementation of the operational-level model

The designed model is done in two stages. The first step is to determine the priority of goals using AHP and Super Decision software, and in the second step, goal planning is solved in three ways: ordinal, preemptive, and fuzzy goals using Lingo13 software.

Table 5: Index description of parameters

Index of parameters	i	k	w	m	p	z	u	t	r
Definition	Supplier	Customer	Store	Collection center	Separation center	Decomposition center	Repair center	Means of transportation	Raw material
Count	8	4	2	1	1	1	1	6	8

The number of goals, limits, and variables according to the type of modeling (deterministic goal-fuzzy goal) is as described in Table (6):

Table 6: Type and number of variables and constraints

Description	Type	**Number of components in each model**	
		Definite	Fuzzy
Variables	Main	209	209
	Fuzzy	-	1
	Deviation from the goal	6	6
	Total	215	216
Limitations	Main	369	361
	Fuzzy	-	9
	Goal	6	6
	Total	375	376
Goals	6 goals		

The decision hierarchy tree is drawn to determine the priority of the goals in the supply chain, as Figure (3, so that the information can be collected from the experts in the next steps.

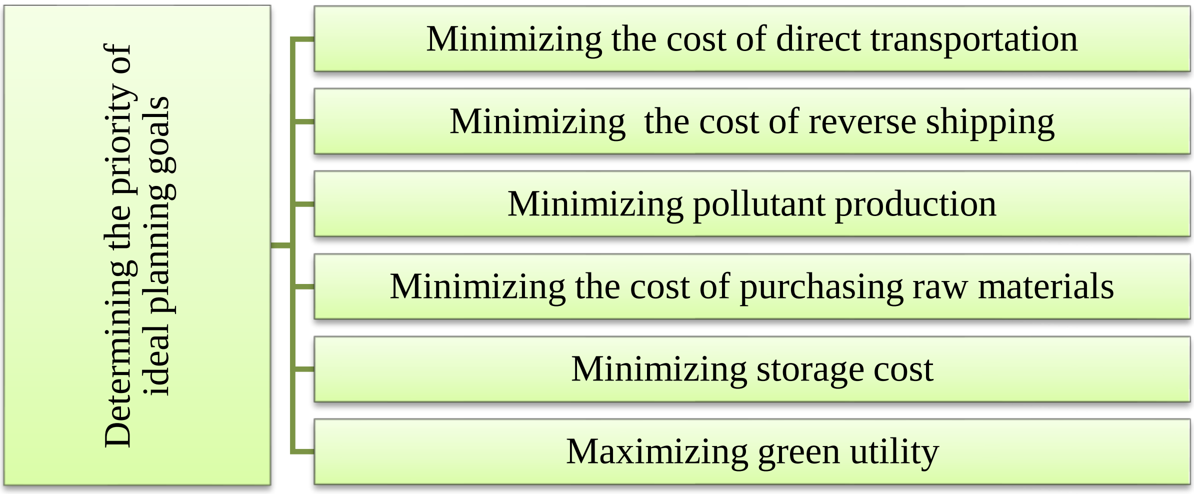

Figure 3: Decision tree for determining the priority of goal supply chain planning objectives

After completing the table of paired comparisons by the experts, first, its compatibility rate was calculated, which was less than 0.1, and indicates the compatibility of the comparisons. Finally, the weights of the goals were obtained according to Table (7):

Table 7: Intensity of different objectives importance in the goal supply chain model

Goals	Intensity of importance
Minimize direct shipping cost	0.142
Minimize the cost of reverse shipping	0.146
Minimize pollutant production	0.515
Minimizing the cost of purchasing raw materials	0.13
Minimize storage cost	0.03
Maximizing green utility	0.152

Due to the lack of information, the cost of keeping materials in the raw material warehouse is considered being almost the same. The purchase price, supplier capacity, inventory at the beginning of the period, shortage, and storage cost are shown in Table (8).

Table 8: Raw material parameters

Raw material (unit)	Parameter	Purchase price (IRR)	Supplier capacity	Balance at the beginning of the period	Maintenance fee (IRR)
Type 1 (ton)		1500000	600,000	26	750,000
Type 2 (ton)		1800000	1200000	20	900,000
Type 3 (ton)		1000000	400,000	30	500,000

ISSN: 2037-4445

Type 4 (ton)	1400000	400,000	585	700,000
Type 5 (square meter)	175,000	300,000	3000	600,000
Type 6 (square meters)	160,000	100,000	1000	600,000
Type 7 (square meter)	160,000	100,000	1000	600,000
Type 8 (kg)	40000000	40,000	20	600,000

The second part of the supply chain that closes its loop is reverse logistics. This facility comprises a collection center, a separation center, a decomposition center, a repair center, and a final waste site.

The rate of this amount of returns is shown in Table (9).

Table 9: Return rate in reverse logistics mechanism

	Symbol	Amount (%)
Lowest rate of return from customer k	lbk	-
Highest rate of return from customer k	ubk	-
Product shipping rate from collection to repair	β	10
Product return rate from repair to warehouse	χ	90
Shipping rate from segregation to final waste	δ	0.5
Rate of return from decomposition to primary suppliers	ε_r	90

Fuzzy Model

***Z*¹ and *Z*⁰ values**

For this purpose, if we consider the following basic linear programming model,

Max $f(x)=C_T X$

s. to:

$Ax \le b$

To convert the above model into a model with a fuzzy constraint and a definite objective function, we will have:

$\text{Max}\, Z = \lambda$

$C^T X-(Z^1- Z^0)\lambda \ge Z^0$

s. to:

$Ax+p\lambda \le b+p$

$\lambda, x \ge 0$

Clearly, the values of Z^1 and Z^0 are the maximum and minimum values of the initial model, so the following model was used to attain the minimum value (Z^0):

$\text{Max}\, f(x) = C^T X$

s. to:

$Ax \le b$

$x \geq 0$

Likewise, to reach the maximum value (Z^1), the following model is used:

$\mathrm{Max}\ \mathrm{f(x)} = C^T X$

s. to:

$Ax \leq b+p$

$x \geq 0$

By solving the above two models, the maximum value of Z^1 and minimum value of Z^0 are as follows:

Table 10: Z^1 and Z^0 values in the fuzzy model

Max. (Z^1)	0.099591949
Min. (Z^0)	0.099382836

To determine the range of phase changes for the upper and lower limits, 10% of the desired limit was considered as the range of phase changes of that limit.

Table 11: Type and number of research model solutions

Purpose of solving the model	Number of the model solution
To calculate goals	6
Deterministic-ordinal model	1
A priori deterministic model	3
Fuzzy model	1
Calculation of Z0 and Z1 in the fuzzy model	2

Results of solving the deterministic model

In this section, the results of solving the deterministic model will be presented. According to the extensive results, the most important of them, i.e. goals and objective function, will be presented in the following table. The deterministic goal model is solved in two ordinal and preemptive modes.

Table 12: Degree of realization of each goal in the deterministic goal model (ordinal)

Goal number	Type of goal	Deviation type	Optimal target value	The goal value after solving	Deviation value	The degree of realization of the goal
First	Min	d_1^+	5590000000	5701800000	111800000	98%
Second	Min	d_2^+	1200000000	1200000000	0	100%
Third	Min	d_3^+	1200000000	1200000000	0	100%

Fourth	Min	d_4^+	66000000000	70620000000	4620000000	93.99%
Fifth	Min	d_5^+	1880000000	1887520000	7520000	99.996%
Sixth	Max	d_6^-	18802	6956	11846	37%
Overall	Min			0.15		

Based on the experts' opinion, in the deterministic preemptive model, the priorities of solving the model were considered as follows:

First preemptive: Minimizing the production of greenhouse gases; maximizing green utility; minimizing reverse logistics costs;

Second preemptive: Minimizing direct transportation costs;

Third preemptive: Minimizing the costs of purchasing raw materials and storage;

Table 13: Degree of realization of each goal in the deterministic goal model (preemptive)

Goal number	Type of goal	Deviation type	Optimal target value	The goal value after solving	Deviation value	The degree of realization of the goal
First	Min	d_1^+	5590000000	5590559000	559,000	99.9999%
Second	Min	d_2^+	1200000000	1200000000	0	100%
Third	Min	d_3^+	1200000000	1200000000	0	100%
Fourth	Min	d_4^+	66000000000	66462000000	462000000	99.993%
the fifth	Min	d_5^+	1880000000	1887520000	7520000	99.996%
the sixth	Max	d_6^-	18802	18802	0	100%
overall	Min			0.01		

Results of solving the fuzzy model

In this section, the results of solving the fuzzy model will be offered. Based on the extensive results, the most significant ones, i.e. goals and objective function, will be presented in Table 14. The limitation of returning the product from the customer to the recycling cycle is considered a fuzzy parameter.

Table 14: Results of solving the fuzzy model

Goal No.	Type of goal	Optimal target value	Goal value after solving	Deviation value	Degree of goal realization
First	Min	5590000000	5645900000	55900000	99.99%
Second	Min	1200000000	1200000000	0	100%
Third	Min	1200000000	1200000000	0	100%
Fourth	Min	66000000000	66264000000	264000000	99.994%
Fifth	Min	1880000000	1887520000	7520000	99.996%
Sixth	Max	18802	6956	11846	37%
Total deviations	Min		0.0994		
λ	Max		0.502		

It is essential to make a comparison between two ordinal and preemptive solving methods despite the preemptive in achieving goals for decision-makers.

Table 15: Comparison of the solution results of ordinal and preemptive deterministic model

Goal number	Optimum value of the goal	Deterministic model	Fuzzy model	Percentage improvement of the preemptive compared to ordinal model
		Amount	Amount	
First	5590000000	5701800000	5590559000	1.99
Second	1200000000	1200000000	1200000000	0
Third	1200000000	1200000000	1200000000	0
Fourth	66000000000	70620000000	66462000000	6.3
Fifth	1880000000	1887520000	1887520000	0
Sixth	18802	6956	18802	63
Total deviations		0.15	0.01	

Table (16) summarizes the values of goals and objective function in the deterministic model and fuzzy model, as well as the amount of improvement in achieving them if each model is used.

Table 16: Comparing the value of goals in two deterministic and fuzzy models

		Deterministic model	Fuzzy model	

Goal number	Optimum value of the goal	Amount	Amount	Percentage improvement of the fuzzy model compared to deterministic
First	5590000000	5701800000	5645900000	1
Second	1200000000	1200000000	1200000000	0
Third	1200000000	1200000000	1200000000	0
Fourth	66000000000	70620000000	66264000000	6.6
Fifth	1880000000	1887520000	1887520000	0
Sixth	18802	6956	6956	0
Total deviations		0.15	0.09	

Table 17: Comparison of reverse logistics outputs in two deterministic and fuzzy models

Variable	Definition	Deterministic Model	Fuzzy Model
$\boldsymbol{K^{1m}}$	Amount of product shipped from customer 1 to the collection center m	700	630.29
$\boldsymbol{K^{2m}}$	Amount of product shipped from customer 2 to the collection center m	600	540.25
$\boldsymbol{K^{3m}}$	Amount of product shipped from customer 3 to the collection center m	500	450.21
$\boldsymbol{K^{4m}}$	Amount of product shipped from customer 4 to the collection center m	400	360.16
$\boldsymbol{T^{m}}$	Amount of product transported from the collection center m to the repair unit	220	198.092
$\boldsymbol{O^{w}}$	Amount of product transported from the repair unit to the warehouse w	198	178.28
$\boldsymbol{S^{mp}}$	Amount of product transported from the collection center m to the separation center p	1980	1783.83
$\boldsymbol{D^{p}}$	Amount of product transported from the separation center p to the final waste site	9.9	8.91
$\boldsymbol{F^{pz}}$	Amount of product transported from the separation center p to the separation center z	1970	1773.92
$\boldsymbol{G^{zi}}$	Total amount of recycled type raw glass shipped from decomposition center z to supplier i	1772	1596
$\boldsymbol{G^{zi}}$	Total amount of recycled PVB transported from the decomposition center z to the supplier i	195	175.6

Conclusion

The key research approach has been to design and offer a mathematical model for green supply chain management. Based on the results, the results show that to green the structure of an organization, although macro-level and top management decisions with a weight of 0.362 are very important, green performance is considered more important and the operational level with a weight of 0.506 has a greater effect on greening an organizational structure and last, the middle level has the least weight with 0.131. At the operational level, saving energy and raw materials with a weight of 0.818 shows that saving by employees plays a significant role. At the level of excellent management, waste management, reverse logistics, and comprehensive quality programs with a weight of 0.565, and creating research and development capacity, technology and design in preventing pollution and saving energy and materials with a weight of 0.233 will have the greatest effect. With over seven times the weight of the training of the forces committed to green principles, incessant supervision and regular middle-level commitment to the principles explained by the top management will not be ineffective in the meantime.

According to the results in the preemptive model, there is a 63% improvement in increasing green utility, a 1.99% improvement in purchase costs, which is equivalent to 1,11241,000/-IRR, and a 6.3% improvement in the cost of purchasing raw materials, which is equivalent to 4,499,060,00-/IRR. This amount of improvement is because of the sale of recycled glass and polymer film to the primary suppliers. There is no precise data on the real parameters, but the survey conducted by the experts regarding the outputs of the model, the improvement of the purchase costs, the increase of the transportation costs, and the transfer and reduction of carbon dioxide production was roughly approved by the experts.

Though trucks with 0 to 3 years of service cause more transportation costs, they cause less pollution because of their technical health. Consistent with environmental activities, in EU member states, every industry may produce a standard amount of greenhouse gases, and in case of producing each additional gram, it must pay a fine of 5 cents to the government (Paksoy et al., p. 10, 2012). It is in this situation that producers face fundamental limitations in their production mechanism.

Because of clear data from the existing reality, the outputs were only approved or rejected by the company's experts. Based on the results, though in both deterministic and fuzzy models, the amount of green desirability has increased by the same amount. In the fuzzy model, transportation costs are reduced by 1%, which is equivalent to 5,590,000-/IRR. Since the return rate of the product from the customer and being placed in the recycling cycle is considered in a fuzzy manner and is closer to its actual value, there has been an improvement of 6.6% in the purchase cost of raw materials, which is equivalent to 43560000000. This improvement is because of the sale of recycled glass and polymer film to primary suppliers.

Using the goal of the research model has many positive results for the companies that use it. Instead of pursuing a specific goal, for example, reducing costs, the use of the designed goal model permits the company to consider numerous diverse goals together. Likewise, considering the process of network analysis provides this possibility for company management to determine the weights of suppliers and customers and the number of purchases from them, and simply and scientifically. Alternatively, by applying the mathematical model, the production level of the product is based on the amount of demand and resources, and it can be accepted that the amount of production is not more than the required amount, and we will not face excess stock in the warehouses, and all the demands have been answered. With the application of the model, it can be accepted that the solution of the models offers the optimal situation of the amount of purchase from suppliers, the choice of the suitable means of transportation with the environment, the optimal amount of production and delivery to the final customer based on the company's priorities. Solving the goal planning fuzzy model decides makers the confidence that the model outputs will be closer to the real world.

To have an integrated green supply chain, the supply chain in industries that are directly or indirectly related to glass can be recognized with a green approach. In internal and external chains, units recognize each other as customers.

Conversely, in-charge units such as HSE manage pollutant production and energy consumption at the level of the value chain with the GrSCM approach. Likewise, the top management of the organization should take steps to generate a waste management mechanism, reverse logistics, and inclusive quality programs, and create research and development, technology, and design capacity to prevent pollution and save energy and materials. Altering behavior and insight leads to changing behavior. Pertinent training for senior managers and employees about clarifying the necessity of environmental issues can be efficient in the long run. Lastly, investing in technologies that eliminate or reduce pollution sources.

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