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Mathematical Modeling for Sustainability Evaluation in a Multi-Layer Supply Chain

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Abstract: Human societies and researchers ensued that the continuation of a one-dimensional development focused on economic benefits can endanger the survival and tranquility of humanity, after experiencing a period of economic development and due to the advantages and disadvantages of this type of development. Concerns and damages of the environment and social challenges have led to the evolution of a three-dimensional concept of development based on economy, environment and society being known as sustainable development. Due to different indicators in each dimension of sustainability, finding effective ones is substantial. Supply chains are one of the most important and comprehensive domains in which sustainability led to better integration of layers and improve the total performance. On the other hand, current literatures demonstrate serious gap in representing comprehensive and integrated guidelines in order to optimize environmental and social indicators impacts in the management of supply chain. In this paper, all possible indicators for sustainability are collected, mapped into the layers of supply chain and inserted to a proposed mathematical model. The outputs are the effective indicators in three dimensions of sustainability for all layers of supply chain maximizing the sustainability of the whole supply chain. The proposed approach is implemented in a fishery supply chain.

Keywords: Sustainable supply chain; Sustainability indicators; Sustainable value; Mathematical model; Fishery industry

1. Introduction

Globalization requires the management of supply chain in order to take step beyond merely economic problems and issues such as equitable work conditions and environmentally friendly manufacturing. Over a 17-year period (1990-2007), Seuring and Müller [1] conducted a review analysis on green and Sustainable supply chain management (SSCM) and researched 191 articles. In the late 2010, the number of articles increased from 191 to 308. The articles were sorted given their research methodology and at last there were 36 articles conducted using quantitative models. The current research aims at conducting a review analysis over a longer period of time compared to what was done by Seuring and Müller [1]. In addition, the scope of this research has been narrowed down to only quantitative models. Therefore, it paves the way to take a deeper look at this stream of research and propose future research suggestions. This study is obviously in contrast with the work conducted by Fleischmann et al. [2] on "quantitative models for reverse logistics" in terms of the number of the models. Additionally, there is a widespread literature on the neighboring fields such as closed-loop supply chains [3], green supply chains with an emphasis on reverse logistics [4], as well as the management of sustainable supply chain [1]. Over recent years, further research has been focused on special topics, and many reviews on the management of sustainable supply chain and inter-organizational resources [5] or SCM- related topics [6] have been published. Conducting a review study, Mollenkopf et al. [7] highlighted the relationship between lean management and globalization problems. By narrowing the focus of their study on particular journals in the logistics and supply chain management (SCM) domain, Carter and Easton [8] assessed the related empirical research studies. However, the review study conducted by them was not focused on quantitative models for forward supply chains. The current research was conducted with the aim to present a summary of quantitative models used for forward supply chains by reviewing the widespread literature existing in this area. Additionally, this research was done with the aim to present a substantive justification which is of considerable importance in theorizing [5] and gives us deeper insights into the directions and needs of future research. Today, public awareness of flawed supply chain has raised a lot. So far, the waste and pollution produced by production companies has been a great threat to the existence of life on earth. Therefore, the existence of these challenges and pressures causes the companies to pay serious attention to the environmental effects while engaging with their business. Due to population growth and resource availability reduction, supply chains need to be redesigned [9]. As the world economic climate develops, uncertainty starts to negatively affect the business environment. Therefore, the organizations need to improve their strategy by reconstructing and restructuring so that they can reinforce the business and profitability and at the same time remain competitive in the marketplace. Furthermore, the media and non-governmental organizations (NGOs) associated with the sustainability dimension of their development will expose organizations to the increased inquiries of the global community [10]. In the view of Porter and Kramer [11], it is increasingly expected from companies to expand their sustainability attempts to the farther side of their operations to embrace their suppliers' and to satisfy their customer's sustainability expectations. Well-known companies in their respective industries take measures to spread sustainability in the supply chain. Carter and Jennings [9] stated that being closed loop, environmentally friendly and conserve and using fewer resources are among the supply chain needs to be met. According to a large number of researchers, sustainability is the future imagined for SCM [9, 12-14]. Different researchers have presented different definitions for the terms 'Sustainable Supply Chain' and 'Supply Chain'. In the view of Leenders et al. [15] supply chain has to do with the relationship between a business and the customers and suppliers. They insist on paying explicit attention to a sustainable supply chain. To put it differently, they persist to consider raw materials and services management from suppliers to producer to customer, and then back, as the social and environmental effect improves. The pressure applied by different shareholders pose a serious challenge to supply chain managers in terms of the integration of sustainable practices to supply chains management. The prerequisite for sustainable supply chain is giving importance to elements such as packaging in an environmental friendly manner, returning of end- of-life and used products to the production system for re-use, and the eco-friendly handling of returns, recycling, remanufacturing and adequately disposing waste [16]. Often, production processes are distributed over a wide area of the world. The information, material and capital flows connect suppliers, focal companies, and customers. Though the product may have a high value, the environmental and social burden it brought with during production stages should be considered. Accordingly, the responsibility of the suppliers' environmental and social performance may be on the supply chains focal companies. Focal companies are defined as companies that rule the supply chain, contact the customer directly, and design the proposed product or service [17, 18]. Brand-owning companies are among focal companies because of the pressure imposed by shareholders, e.g., non-governmental organizations (NGOs) [19, 20]. Due to the existence of the environmental and social problems in the whole supply chain, the companies are expected to pay attention to them. Over recent years, companies working in clothing distribution area like e.g., Nike, Disney, Levi Strauss, Benetton, Adidas or C&A have been responsible for problems occurring during their apparel manufacturing. Among factors mentioned as problematic were inhumane working conditions [21, 22] or the local environment pollutions [23]. Accordingly, integrating environmental and social problems, especially issues embedded in corresponding standards (e.g., ISO 14001) with their everyday duties is considered by operations, purchasing and supply chain managers [24]. These triggers have caused an increase in the interest in the management of green/environmental or sustainable supply chain. Though supply chain has been an object of considerable interest among researchers, the literature still is scant and no comprehensive reviews have been conducted. Of the papers determined as related to the field, eight cases were found that had made attempts to review the literature [25-29]. In the research study conducted by de Burgos and Lorente [25], supply chain issues have been investigated as a secondary topic and the focus is rather on environmental performance as an operation's objective. Similarly, Baumann et al. [27] conducted a study that covered supply chain issued limitedly, they searched 50 issues of ''Production and Operations Management'' and reviewed articles published in the field of ''Sustainable Operations Management''. Using the title of "operations" for their paper, they covered issues related to supply chain. Their work is mainly focused on individual issues and does not provide the reader with a deep insight into the field in terms of its development and status. Additionally, Seuring and Muller [30] conducted a specific review and investigated the emergence and development of integrated chain management in Germany. Though it is closely linked to the management of sustainable supply chain, the close links to industrial ecology and closed-loop SCM were also identified by different schools.

SCM has developed into designing, managing, and optimizing the external and internal parties' activities and their relationships established along a supply chain [31]. SVM aims at better facilitating information and material flows through the integration and collaboration development among supply chain parties so that better relationships can be established [32, 33]. Using the opportunity proposed by SCM, different parties can work along a supply chain and break organizational boundaries to reach a higher level of collaboration [34]. Social, environmental and economic dimensions of sustainability along the supply chain are taken into account in SSCM [35]. To develop supply chain sustainability, all three aspects of sustainability are of considerable importance.

Sustainable production concept, which has a close link with the concept of sustainable development, was coined first at the United Nations Conference on Environment and Development in 1992. According to the conference, the increasing deterioration of the global environment is caused by the unsustainable pattern of consumption and production, which is worsened in industrialized countries [36]. The focus of sustainable consumption is on consumers while sustainable production has to do with companies and organizations manufacturing products or offering services. Though the concept of sustainability is not yet very well known, there is an increasing agreement to take step beyond defining the concept and develop concrete tools to promote and measure achievements.

The main focus of the present paper is on business sustainability. It presents a new methodology to promote and measure the performance of companies according to a sustainable value and production impact factor. The main purpose of this article is to present the results of a comprehensive review on sustainability and supply chain management. Additionally, it aims to present a set of indicators related to a multi-layer supply chain. Moreover, in order to determine indicators, a mathematical model is presented as a generic framework to maximize the sustainability of supply chain.

The remainder of the paper is organized as follows. In Section 2, the concept of optimum sustainable value is presented and the notations of the proposed mathematical model are given. The input data which are collected from a case study in fishery industry are introduced in Section 3. The numerical results are discussed in the Section 4 and the required sustainable indicators in fisheries industry are represented. And finally conclusion and future research directions are presented in Section 5.

2. Optimum Sustainable Value

Despite the fact that most researches have tried to provide a framework that can play an important role in sustainability measurement, but only a few of them have been able to provide a comprehensive and unique indicator for sustainability measurement (The results are only expressed in the form of a number). None of the reviewed studies have benefited from the mathematical programming approach in order to improve the supply chain, and haven't used the indicators in the form of a supply chain and in order to improve the chain.

Also, none of the researchers studied have considered the dynamics of valuation indices as well as the effects of different indices on different layers of the supply chain (the dynamics of the valuation index can be defined as sensitivity (elasticity) of the value of sustainable value to the deviation from the expected level of the indices). The concept of elasticity can prevent the effects of the indices positively or negatively, and have sensitivity to the deviation from the expected level of the indices. One of the disadvantages of this model is the lack of positive environmental and social impacts. Each firm can have positive or negative effects on its society and its environment. Among the positive effects of a firm w can be mentioned, employment creation, equality between women and men, poverty eradication, green space creation, use of organic materials, environmental clean-up (waste collection), helping to promote health, etc. But most of the models already presented, have considered only the negative effects created that the firm has had on its own economic activities on the community and the environment. Given that the aim of our study is to provide a model in the form of supply chain and to determine the benefits of sustainability in the supply chain. Therefore, in developing the mathematical model, a factor is presented to indicate the profit (value acquired) and the lost value. On the other hand, in order to show the relative importance of each of the sustainability indicators in the supply chain, also their economic role in the supply chain in line with the benefits arisen is expressed; we have been looking for a factor that can express this difference in various layers of the chains.

Therefore, in this study, the concept of pricing with linear demand function is used to represent the economic benefits. The aim of the pricing is to express the value of each indicator according to the demand of that indicator in various dimensions of sustainability between supply chain layers. Also, the concept of price elasticity of demand has been used for each indicator for different layers of the supply chain in order to express the relative importance of sustainability indicators and their impact on prices. In the following, the proposed mathematical model is presented based on accepted assumptions and analysis of the proposed models.

As already mentioned, this paper focuses on calculating the optimal sustainable value which was to be calculated first to obtain a stable value, then, using mathematical programming, maximizing the sustainable value obtained by considering the constraints.

The key input of the mathematical programing model is production impact factor (PIF) for sustainable development indicators which represents the amount of indicators per unit of production quantity, and importance coefficient for each indicator. This model determines the optimum quantity of production in order to maximizing the achievable value in three dimension of sustainable development.

In this study, in addition to the sustainable value, the amount of production impact factor is considered, which should be considered in determining the effective indices to maximize the amount of production.

In the following, a seven-step continuous-loop model for defining and measuring sustainable indicators is presented in Figure 1. The first step involves defining sustainable goals and objectives that are consistent sustainable value and production impact factor; these objectives may reflect an industries goals. The second step involves identification of potential indicators to reflect an industries goals and targets toward optimum sustainable value. The third step in the model includes selection of sustainable fisheries indicators for implementation. In addition to the core indicators, sustainable fisheries indicators are considered. Setting targets (step 4) is a key step, where obtained after consulting with experts sets specific goals, such as gaining effective indicators in order to obtain optimal sustainable value and increasing the production impact factor. Indicator implementation (step 5) is a key step that involves data collection, calculation, evaluation and interpretation of results. Step 6 involves monitoring and communicating results which means that the verification is done on the results so that the sustainability indicators associated with this industry are properly extracted. The last step (step 7) includes obtaining the effective indicators, this is a key step, since it lays the grounds for setting new goals and a new way to achieve optimal sustainable value.

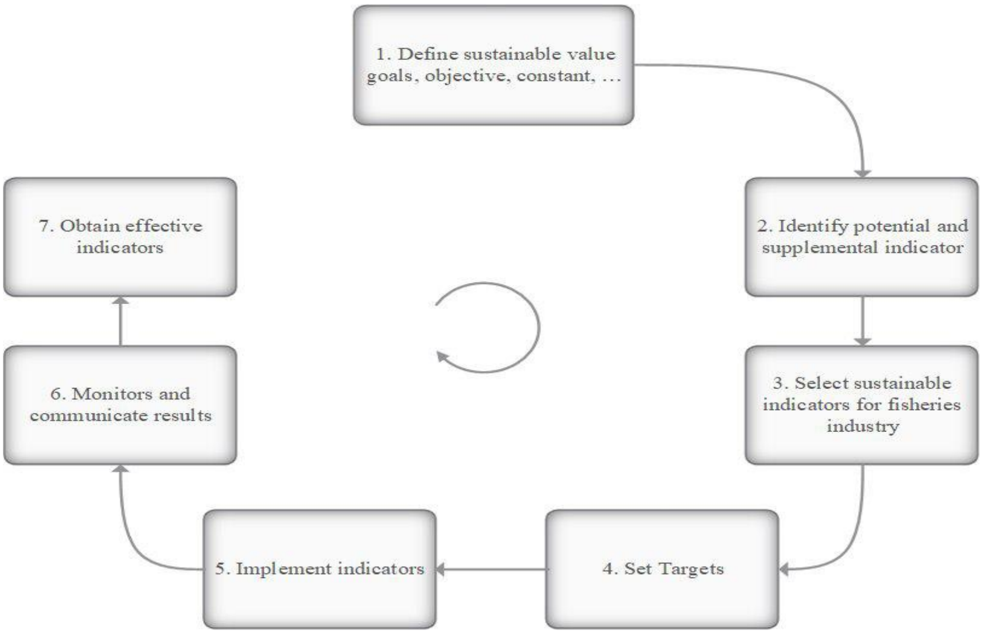

Figure 1. Continues-loop for defining and measuring sustainable indicators

Here, the mathematical model is developed. It is assumed that the value of each indicator is directly related to the production value. For example, by increasing the amount of production, the number of personnel required, the amount of resources, and the consumption of water and energy are also increased. Below, the notations of the mathematical model are given in Tables 1 to 3.

2.1 Indices

Table 1 shows the indexes used in the model and the related explanations.

Table 1. Mathematical programming model indexes

Indices	Description
i	Represents the index of each aspect of the problem, which includes economic, social and environmental dimensions
j	Represents the supply chain layers that include suppliers, growers, distributors, and so on.

2.2 Parameters

The parameters used in the sustainable value optimization model are listed in Table 2, and the explanations for each parameter are also stated.

2.3 Decision Variables

Decision variables are either positive or non-negative. In Table 3, these variables and their associated explanations are expressed.

Table 2. Parameters of the mathematical programming model

Parameters	Description
PIF_{ij}	The factor of the production of the i-th index in the j-th layer, which indicates the value of i-th value per unit of production in the j-th layer, for the investigated firm.
SV_{ij}	Indicates the stable value of the i-th index in the j-th layer
EG	Economic Growth
K_{ij}	The value of the i-th index in the j-th layer
$Elast_{ij}$	The stretching value of the i-th index for the j-th layer
VA_{ij}	Value added i-th index in j-th layer
P_{ij}	The inverse of the demand for the i-th index in the j-th layer
D_{ij}	Demand for the i-th index in the j-th layer
$\bar{d}$	Average demand in the investigated firm
$\bar{p}$	Average price in the investigated firm
β	Slope of estimated price line based on the demand
α	The width of the origin of the estimated price line based on the demand
R	The product of the multiplication of the number of dimensional indicators in the number of supply chain layers
Cap	If the i-th index has the ability to be in the j-th layer is 1, otherwise, it's zero
Q_o	The amount of production in the investigated firm
$MCap$	Maximum capacity at the investigated firm
EP	Export power in the investigated firm
HR	The manpower involved in the investigative firm
EC	Employment Capacity in the investigated Firm
BEP	Production head point at the investigated firm
S_{ij}	The standard i-th index in the j-th layer
m	Number of Indices
n	Number of layers

Table 3. Variables of the mathematical programming model

Variables	Type of variable	Description
Q	True positive	value of productions
X_{ij}	Binary	In the case where the i-th index is in the j-th layer, its value is one, and if not, its value will be zero.

2.4 Mathematical Model

Given that the goal is to maximize the value of the stable, hence the stable value relationship will form the objective function of the problem. Following the necessary changes, the introduction of production impact factor (*PIF*) it will be applied as another target function.

$$Max \sum SV_{ij} X_{ij} \qquad \text{The first objective function}$$
$$Max \sum PIF_{ij} X_{ij} \qquad \text{The second objective function}$$

The Production Effect Factor (*PIF*) is the indicator of the i-th index per unit of production.

$$PIF_i = \frac{\sum_{j=1}^{N} X_{ij}}{Q_0}$$

For example, suppose that the production unit of a firm is 1000 units (Q_o=1000), and the amount of rebuilding its reserves is 50 units ($\sum X_{ij} = 50$), so we have:

$$PIF_{ij} = \frac{\sum X_{ij}}{Q_0} = \frac{50}{1000} = 0.05$$

Constraints are:

$$p_{ij} = \alpha_{ij} - \beta_{ij}.de_{ij} \qquad \forall i, j \tag{1}$$

$$\beta_{ij} = \frac{-\sum_i \sum_j \left(de_{ij} - \overline{d}\right)\left(p_{ij} - \overline{p}\right)}{\sum_i \sum_j \left(p_{ij} - \overline{p}\right)^2} \qquad \forall i,j \tag{2}$$

$$\alpha_{ij} = \overline{d} + \beta_{ij}.\overline{p} \qquad \forall i,j \tag{3}$$

$$\overline{p} = \frac{\sum_i \sum_j p_{ij}}{R} \qquad \forall i,j \tag{4}$$

$$\overline{d} = \frac{\sum_i \sum_j p_{ij}}{R} \qquad \forall i,j \tag{5}$$

$$R = I \times J \qquad \forall i,j \tag{6}$$

$$Q \geq BEP \tag{7}$$

$$MCap = \sum x_{ij}(Q_0 \times SV_{ij}) \leq EP \tag{8}$$

$$\sum x_{ij}(Q_0 \times SV_{ij}) \leq MCap \tag{9}$$

$$\sum x_{ij}(HR \times SV_{ij}) \leq EC \tag{10}$$

$$X_{ij} \leq Cap_{ij} \qquad \forall i,j \tag{11}$$

$$PIF_{ij} \times Q \leq S_{ij} \qquad \forall i,j \tag{12}$$

$$\begin{cases} Q \geq 0 & \\ HR & \textit{Positive}\ \text{Integers} \\ X_{ij} \in \{0,1\} & \end{cases} \tag{13}$$

2.5 Constraints

Relations (1) to (6) compute the impact of pricing concept on sustainability of each indicator. Constraint (7) indicates that the production value is greater, or at least equal to, the production point. Constraint (8) balances production and export power. Constraint (9) represents the maximum capacity of an enterprise with respect to its sustainability dimensions. Constraint (10) states that the number of involved personnel should be equal to the total number of personnel currently employed and the number of people employed or dismissed (firm's employment capacity). Relationship (11) expresses the ability to locate the desired indexes in different layers of the supply chain. Constraint (12) states that the value of the i-th index in the j-th layer is at most equal to the standard value of that index. Finally, the relation (13) specifies the type of variables.

3. Case Study

As a case study, the developed model was implemented in a Fishery industry. In the following, the selected indicators and their quantities for Mazandaran Fisheries Industry is shown in Table 4. It should be noted that basically provided indicators are not widely accepted. The geographic diversity of the natural and human environment requires that appropriate Indicators for the local situation and field research should be selected which have the following three features: (1) be able to cover the needs of different groups (including managers, designers and users), (2) Adequate and accurate information about them should be available and (3) Be able to consider three aspects of sustainable development (economic, environmental and social). Indicators are selected based on the third set of indicators of sustainable development which approved by the Commission on Sustainable Development (CSD) [16] and considering the mentioned features.

Table 4. The input total values for sustainable value

	Indicator type	Value obtained (Lost) Missing value/
Social	The number of female personnel	4,2
	the number of male personnel	5,03
	decayed aquatic animals rate	4,47
	per capita consumption rate of aquatic animals	4,49
	the amount of educational courses	7,67
	distribution of educational and promotional publications	-4,03
	fishing rate (related facilities)	-427.66
	employment of people for fishing	-36,92
	the unit of protection of aquatic animals	3,75
	accused person	1,39
	the number of fishers around the north waters	-110,49
Economic	value-added share of fisheries	4,52
	the investment amount from the public budget	4,42
	rise/fall of the price level (warm-water)	-89,27
	rise/fall of the price level (cold-water)	3,77
	rise/fall of the price level (sturgeon)	-108,68
	rise/fall of the price level (breeding in cage)	55,97
	rise/fall of the price level (breeding sturgeon)	4,53
	production value	4,27
	fishing rate (material usage)	4,84
	total production amount	-4,85
	the amount of water resources usage	4,48
	the request made by processing industries	4,52
	the request capacity created for processing industries	4,83
	the number of vessels	4,31
	the performed projects related to the bio-environmental responsibility	4,49
Environmental	the products resulted from recycled materials	4,52
	the production capacity of recycled products	4,37
	the number of raising farms	4,28
	the area of raising farms	-0.97
	the capacity of raising farms	6,42
	the processing rate of the products	4,71
	the jobs created by product processing	4,45
	the area of natural and unnatural water resources usage	-20,47
	the usage amount of natural and unnatural water resources	4,47
	Shoaling	4,53
	releasing baby fish	4,45
	the number of species exposed with risk	4,51
	the number of decorative fish	4,5
	the amount of decorative fish production	-19,99

3.1 Parameters of the Fisheries Industry

In this section, using data from Mazandaran Fisheries and the mathematical model, parameters required to be inserted to the mathematical model with the aim of maximizing the sustainable value and the factor of the production of fisheries, is presented in Table 5.

Table 5. Indicators and their parameters quantities related to the fisheries industry

Parameter	value	Parameter	value
n	40	BEP	24462
EP	8953000	$MCap$	71784000
m	5	HR	4500
QQ	500	EC	11687000
PIF_1	0,04	PIF_2	0,28
PIF_3	0,0096	PIF_4	0,025
PIF_5	3,173	PIF_6	0,514
PIF_7	56,068	PIF_8	9
PIF_9	0,649	PIF_{10}	0,442
PIF_{11}	23,95	PIF_{12}	0,001
PIF_{13}	1,161	PIF_{14}	529,8
PIF_{15}	230,4	PIF_{16}	800
PIF_{17}	300	PIF_{18}	0,64
PIF_{19}	1,696	PIF_{20}	48,92
PIF_{21}	123,48	PIF_{22}	0,428
PIF_{23}	0.020	PIF_{24}	6,94
PIF_{25}	1,79	PIF_{26}	0.109
PIF_{27}	0,024	PIF_{28}	8,27
PIF_{29}	5,076	PIF_{30}	31,001
PIF_{31}	123,316	PIF_{32}	5,860
PIF_{33}	1,535	PIF_{34}	1138,27
PIF_{35}	0,428	PIF_{36}	0,016
PIF_{37}	0,123	PIF_{38}	0,008
PIF_{39}	0,063	PIF_{40}	467,88
S_1	978	S_2	6878
S_3	235	S_4	618
S_5	77613	S_6	12573
S_7	1371545	S_8	22015
S_9	1588	S_{10}	1081
S_{11}	58598	S_{12}	5
S_{13}	23395	S_{14}	129599
S_{15}	28395	S_{16}	195696
S_{17}	807246	S_{18}	15658
S_{19}	1414876	S_{20}	1196789
S_{21}	3018229	S_{22}	10479
S_{23}	508	S_{24}	169639
S_{25}	44002	S_{26}	2671
S_{27}	587	S_{28}	213308
S_{29}	124188	S_{30}	758498
S_{31}	3016556	S_{32}	143366
S_{33}	37563	S_{34}	2784436
S_{35}	10479	S_{36}	392
S_{37}	3013	S_{38}	195
S_{39}	1555	S_{40}	114452

4. Numerical Results

To examine the validity and efficiency of the model, a real problem is solved as the case study regarding the mentioned data and by multi choice goal programming with utility function method and its results are examined. To obtain the values of lower and upper bound of the goal, at first, the problem is solved as single-objective for any objective function with all restrictions and the optimum answer is taken as the upper bound of the goal (regarding that the problem is a maximum-making one). Then, the problem is solved in anti-ideal state (i.e., the objective function of maximum-making is solved in minimum-making state) and the lower bound of the goal is calculated based on the decision-makers view. The values results of lower and upper bound of the goal for every objective function and the resulted values for objective functions are shown in Table 6 after solving the ideal model and the values of deviations where U_{max} and U_{min} are upper and lower bounds for the ideal problem, respectively and Value is the obtained amount in the ideal model.

Table 6. The values of the objective function of goal programming

	Umax	Umin	Value	d	Gap (%)
Z1	275,764	-982,78	275,764	0	0
Z2	4957,055	0	4957,055	0	0

where, in Table 6 d is the amount of deviation of any of the objective functions from the ideal amounts. The last column of Table 6 shows the gap between the ideal answer of every objective function and the value obtained after solving MCGP-U problem. For example, the gap of the first objective function is calculated by the following relation:

$$Gap\% = \frac{value^{*} - U_{1.\max}}{U_{1.\max}} \times 100$$

According to the results given in Table 6, all values obtained in two functions are in the tolerance mentioned as upper and lower bounds. On one hand, the value of deviation is zero for both functions which means that both functions are completely satisfied. Therefore, the value of the functions with upper bound (U_{max}) is equalized which means that the maximum utility is achieved. The results obtained from solving the model and the values chosen by decision variables are presented in Table 7.

Table 7. The results of solving the model and the values adopted by the decision variables

X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0
2	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
3	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
5	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	0
X	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	0	1	1	1	0	0	1	1	0	0	0	0	0	1	1	0	0	0	1	1
2	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1	1
3	1	0	1	1	0	0	1	1	0	0	0	1	1	0	0	1	1	1	1	1
4	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Q										24462					

Regarding Table 7, the columns show the indices and the rows indicate the layers. For example, index 4 chooses 1 in layers 3 and 5. This means that this index helps to increase the sustainable value and the impact factor of production at the same time for the corresponding supply chain layers. Regarding the balance of the two objectives, the responses which are effective on the optimum answer of both objective functions are excluded. Some of the indices with negative sustainable value are observed in the output, while by just considering the first objective function, the outputs include the positive sustainable values and by considering the second objective function, all of the responses came out as answers. This point indicates the importance of the decision-maker`s view in optimization.

4.1 Discussions

Basically, the indicators are not universally accepted, so that there has not been a series of common indicators so far can be universally accepted. Due to geographical variation of human and natural environments, it is necessary that some indicators be selected that are appropriate to the local situation and the field of research, these indicators should be measurable, reproducible, sensitive relative to the time and place, dependent on human effects, conceptually applicable, and simple to collect, express the unique features, as comprehensive as possible indicate the process of changes. Therefore, the sustainability indicators used in the fisheries industry are shown in Tables 8, 9 and 10. As shown in the tables, we have presented a unique index related to the industry considering the subgroups of effects, as well as considering the features related to the fisheries industry.

After studying the subgroups of sustainability effects in fisheries, Tables 8, 9, and 10, the values of the sustainability indices needed to obtain a sustainable value over 5 years, the sum and its average using the tensile formula, the tensile values of each index are calculated and in the next step, the value of the sustainable value of each index is obtained using the valuation formula.

Table 8. Sub-theme of social effects

sub-theme		core indicator*	fisheries industry
Equality and Justice	poverty Gender equality The welfare of children	• Proportion of population living below national poverty line • Ratio of share in national income of highest to lowest quintile • Proportion of population using an improved sanitation facility • The unemployment rate • Per capita social benefits • The ratio of women's employment to men	The number of men and women
Health	Nutritional status Health status and risks mortality Healthy drinking water health care delivery	• Life expectancy at birth • Percentage of people who can have access to sanitation systems for water and wastewater • the cost of providing government health care services • immunization against children's diseases	The amount of lost aquatic animals per capita aquatic animals
Education	education level literacy	• Gross intake ratio to last grade of primary education • Net enrolment rate in primary education • Adult secondary (tertiary) schooling attainment level	The amount of training courses in the fisheries industry Distribution of educational and promotional publications to promote public awareness for the conservation and rehabilitation of aquatic resources
Housing	life conditions	• The amount of diversity and equal opportunity • Number of rooms per person	Facilities for Fisheries
Security	Crimes	• The number of offenders	Aquatic Protection Unit
Population	Population change	• Population growth rate • Population density • Net migration rate	The number of people employed in the fishing industry directly

* UN.org

Table 9. Sub-theme of economic effects

sub-theme		core indicator*	fisheries industry
economic development	macro-economic performance	• Gross domestic product (GDP) per capita • Investment share in GDP • Added value of economic sectors Added value of economic sectors	The share of the value added of the fisheries from the value added of the industry the investment made in the fisheries from the public budget
	Trade	• Current account deficit as percentage of GDP • Inflation rate • Trade with international markets	the increase / decrease in the price level of the goods or services of the fisheries industry
	Financial situation	• General government debt • Helping developing countries	the income of the fisheries industry, and obtaining the rapid ratio for this industry
Consumption and production patterns	Material consumption	• Material intensity of the economy	the total production rate of the fisheries industry
	Energy use	• Annual energy consumption, total and by main user category • Intensity of energy use, total and by economic activity • Share of renewable energy sources in total energy use	the amount of water withdrawal from water resources

	Waste generation and management	• Generation of hazardous waste • Waste treatment and disposal • Management of radioactive waste	the number or demand created for the use of process industries
	Transportation	• Modal split of freight transport • Energy intensity of transport	the demand for the transportation of materials by its type in the fisheries industry (number of *fishing vessel*s)
	Environmental Protection	• Government expenditure on environmental protection	the number of project conducted related to environmental accountability in the fisheries Industry

* UN.org

Table 10. Sub-theme of environmental effects

sub-theme		core indicator*	fisheries industry
Atmosphere	Climate change	• Carbon dioxide emissions • Emissions of greenhouse gases	Number of units for products obtained from recycled materials in the fisheries industry
	Ozone layer depletion	• Consumption of ozone depleting substances	
	Air quality	• Ambient concentration of air pollutants in urban areas	
Land	Land use and status	• Land use change • Land degradation	fish hatcheries (Extent of usable land)
	Desertification	• Land affected by desertification	
	Agriculture	• Arable and permanent cropland area • Fertilizer use efficiency • Use of agricultural pesticides • Area under organic farming	
	Forests	• Proportion of land area covered by forests • Percent of forest trees damaged by defoliation • Area of forest under sustainable forest management	
Oceans, seas and coasts	Coastal zone	• Percentage of total population living in coastal areas • Bathing water quality	number (demand) of businesses related to processing of fisheries products
	Fisheries	• Proportion of fish stocks within safe biological limits	
	Marine environment	• Proportion of marine area protected • Annual catches of important or endangered fish	
Freshwater	Water quantity	• Proportion of total water resources used • Water use intensity by economic activity	withdrawal from natural and semi-natural water resources
	Water quality	• Presence of faecal coliforms in freshwater • Biochemical oxygen demand in water bodies • Wastewater treatment	regeneration of aquatic animals stocks
Biodiversity	Ecosystem	• Proportion of terrestrial area protected, total and by ecological region • Management effectiveness of protected areas • Area of selected key ecosystems • Fragmentation of habitats • Change in threat status of species • Abundance of selected key species • Abundance of invasive alien species	Number of endangered species in the fisheries industry ornamental fish production

* UN.org

5. Conclusions

This study considered the proposed framework for evaluation of sustainability, in order to maximize the sustainable value of the designed multi-layer supply chain a mathematical programming model was presented. The proposed model has maximized the sustainable value and the magnitude of the effect of production by determining the effective indices and considering the constraints of the problem, such as the limitation of production capacity, manpower, and export power and by using multi-choice goal programming, taking into account the utility function. Then, the fisheries industry has been investigated as a case study in order to explain the proposed model and how to implement it in practice. Some of the most effective indicators in this industry which was the output of the mathematical model include: per capita consumption of aquatic animals, the production value, water withdrawal from water resources, the number of units associated with recycled products, the amount of employment created, as well as the amount of processing, etc. This means that this index will increase the sustainable value as well as production impact factor simultaneously on these different layers of supply chain is related to this industry. Given that the balancing of the two objective functions simultaneously removes the responses that affect the optimal solution of both objective functions. Some indicators have been observed with the negative value of sustainable value in the outputs, while only considering the first objective function, the outputs include positive values of the sustainable value, and taking into account the second objective function, all the responses are removed as solution. The sensitivity of the model to the decision maker's perspective in the optimization process is reflected by this point. Considering these, the sustainable value obtained for this industry is 275,764 billion Rials. (Applying the above changes will result in an improvement of about 30% in the value of the sustainable value). We have been looking to take effective steps to increase sustainability using the value gained with regard to the value of the indicators that affect the supply chain.

Data Availability

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] S. Seuring and M. Müller, "From a literature review to a conceptual framework for sustainable supply chain management," *J. Clean. Prod.*, vol. 16, no. 15, pp. 1699-1710, 2008. https://doi.org/10.1016/j.jclepro.2008.04.020.

[2] M. Fleischmann, J. M. Bloemhof-Ruwaard, R. Dekker, E. van der Laan, J. A. E. E. van Nunen, and L. N. Van Wassenhove, "Quantitative models for reverse logistics: A review," *EUR. J. Oper. Res.*, vol. 103, no. 1, pp. 1-17, 1997. https://doi.org/10.1016/S0377-2217(97)00230-0.

[3] V. D. R. Guide, V. Jayaraman, R. Srivastava, and W. C. Benton, "Supply chain management for recoverable manufacturing systems," Interfaces, vol. 30, no. 3, pp. 125-142, 2000.

[4] S. Srivastava, "Green supply-chain management: a state-of the-art literature review," *Int J. Manag. Rev.*, vol. 9, no. 1, 53-80, 2007. https://doi.org/10.1111/j.1468-2370.2007.00202.x.

[5] S. Gold, S. Seuring, and P. Beske, "Sustainable supply chain management and inter-organizational resources: A literature review," *Corp. Soc. Responsib. Environ. Manag.*, vol. 17, no. 4, pp. 230-245, 2010. https://doi.org/10.1002/csr.207.

[6] S. Gold, S. Seuring, and P. Beske, "The constructs of sustainable supply chainmanagement: A content analysis based on published case studies," *Prog. Ind. Ecol. Int J.*, vol. 7, no. 2, pp. 114-137, 2010. https://doi.org/10.1504/PIE.2010.036045.

[7] D. Mollenkopf, H. Stolze, W. L. Tate, and M. Ueltschy, "Green, lean, and global supply chains," *Int J. Phys. Distr. Log. Manage.*, vol. 40, no. 1-2, pp. 14-41, 2010. https://doi.org/10.1108/09600031011018028.

[8] C. R. Carter and P. L. Easton, "Sustainable supply chain management: evolution and future directions," International Journal of Physical Distribution & Logistics Management, vol. 41, no. 1, pp. 46-62, 2011. https://doi.org/10.1108/09600031111101420.

[9] C. R. Carter and M. M. Jennings, "Logistics social responsibility: An integrative framework," *J. Bus. Logist.*, vol. 23, no. 1, pp. 145-180, 2002. https://doi.org/10.1002/j.2158-1592.2002.tb00020.x.

[10] J. Sarkis, "Manufacturing's role in corporate environmental sustainability," *Int J. Oper. Prod. Man.*, vol. 21, no. 5-6, pp. 666-686, 2001. https://doi.org/10.1108/01443570110390390.

[11] M. E. Porter and M. R. Kramer, "Strategy and society: The link between competitive advantage and corporate social responsibility," *Harvard Bus. Rev.*, vol. 84, no. 12, pp. 78-92, 2006.

[12] C. R. Carter and M. M. Jennings, "The role of purchasing in the socially responsible management of the supply chain: A structural equation analysis," *J. Bus. Logist.,* vol. 25, no. 1, pp. 145-186, 2004. https://doi.org/10.1002/j.2158-1592.2004.tb00173.x.

[13] P. R. Murphy and R. F. Poist, "Socially responsible logistics: An exploratory study," *Transport. J.*, vol. 41, no. 4, pp. 23-35, 2002.

[14] P. Penfield, Seven steps to implementing a sustainable supply chain, USA: White Report, pp. 10-11, 2009.

[15] M. R. Leenders, P. F. Johnson, A. E. Flynn, and H. E. Fearon, Purchasing and Supply Management, USA: Irwin, 2006.

[16] Q. H. Zhu, J. Sarkis, and Y. Geng, “Green supply chain management in China: Drivers, practices and performance,” *Int J. Oper. Prod. Man.*, 25, no. 5, pp. 449-468, 2005. https://doi.org/10.1108/01443570510593148.
[17] R. B. Handfield and E. L. Nichols, Introduction to Supply Chain Management, UK: Pearson, 1999.
[18] P. Schary and T. Skjott-Larsen, Managing the Global Supply Chain, Denmark: Copenhagen Business School Press, 2001.
[19] C. R. Carter and M. M. Jennings, “Social responsibility and supply chain relationships,” *Transp. Res. E Logist. Transp. Rev.*, vol. 38, no. 1, pp. 37-52, 2002. https://doi.org/10.1016/S1366-5545(01)00008-4.
[20] G. Kovács, “Framing a demand network for sustainability,” *Prog. Ind. Ecol. Int J.*, vol. 1, no. 4, pp. 397-410, 2004. https://doi.org/10.1504/PIE.2004.005843.
[21] L. Preuss, “In dirty chains? Purchasing and greener manufacturing,” *J. Bus. Ethics*, vol. 34, no. 3-4, pp. 345-359, 2001. https://doi.org/10.1023/A:1012549318786.
[22] J. J. Graafland, “Sourcing ethics in the textile sector: The case of C&A,” *Bus. Ethics Eur. Rev.*, vol. 11, no. 3, pp. 282-294, 2002. https://doi.org/10.1111/1467-8608.00286.
[23] S. Seuring, “Green supply chain costing - joint cost management in the polyester linings supply chain,” *Greener Man. Int.*, vol. 33, pp. 71-80, 2001.
[24] P. Beske, J. Koplin, and S. Seuring, “The use of environmental and social standards by German first-tier suppliers of the Volkswagen AG,” *Corp. Soc. Resp. Environ. Mange.*, vol. 15, no. 2, pp. 63-75, 2008. https://doi.org/10.1002/csr.136.
[25] J. de Burgos-Jiménez and J. J. Cespedes-Lorente, “Environmental performance as an operations objective,” *Int J. Oper. Prod. Manag.*, vol. 21, no. 12, pp. 1553-1572, 2001. https://doi.org/10.1108/01443570110410900.
[26] G. A. Zsidisin and S. P. Siferd, “Environmental purchasing: A framework for theory development,” *Eur. J. Purch. Supply Manag.*, vol. 7, no. 1, pp. 61-73, 2001. https://doi.org/10.1016/S0969-7012(00)00007-1.
[27] H. Baumann, F. Boons, and A. Bragd, “Mapping the green product development field: Engineering, policy and business perspectives,” *J. Clean. Prod.*, vol. 10, no. 5, pp. 409-425, 2002. https://doi.org/10.1016/S0959-6526(02)00015-X.
[28] S. M. Abukhader and G. Jönson, “Logistics and the environment: is it an established subject,” *Int J. Logist-Res. App.*, vol. 7, no. 2, pp. 137-149, 2004. https://doi.org/10.1080/13675560410001684201.
[29] P. R. Kleindorfer, K. Singhal, and L. N. Van Wassenhove, “Sustainable operations management,” *Prod. Oper. Manag*., vol. 14, no. 4, pp. 482-492, 2005. https://doi.org/10.1111/j.1937-5956.2005.tb00235.x.
[30] S. Seuring and M. Müller, “Integrated chain management in Germany - identifying schools of thought based on a literature review,” *J. Clean. Prod.*, vol. 15, no. 7, pp. 699-710, 2007. https://doi.org/10.1016/j.jclepro.2005.12.005.
[31] R. E. Spekman, J. W. Kamauff, and N. Myhr, “An empirical investigation into supply chain management: A perspective on partnerships,” *Supply Chain Manag. Int. J.*, vol. 3, no. 2, pp. 53-67, 1998. https://doi.org/10.1108/13598549810215379.
[32] A. Ashby, M. Leat, and M. Hudson-Smith, “Making connections: a review of supply chain management and sustainability literature,” *Supply Chain Manag. Int. J.*, vol. 17, no. 5, pp. 497-516, 2012. https://doi.org/10.1108/13598541211258573.
[33] R. Handfield and E. Nichols, Introduction to Supply Chain Management, UK: Pearson, 1999.
[34] R. Frankel, Y. A. Bolumole, R. A. Eltantawy, A. Paulraj, and G. T. Gundlach, “The domain and scope of SCM's foundational disciplines-insights and issues to advance research,” Journal of Business Logistics, vol. 29, no. 1, pp. 1-30, 2008. https://doi.org/10.1002/j.2158-1592.2008.tb00066.x.
[35] C. R. Carter and D. S. Rogers, “A framework of sustainable supply chain management: Moving toward new theory,” *Int. J. Phys. Distrib. Logist. Manag.*, vol. 38, no. 5, pp. 360-387, 2008. https://doi.org/10.1108/09600030810882816.
[36] R. de Janeiro, "Agenda 21: Programme of Action for Sustainable Development," In United Nations Conference on Environment and Development, Brazil, 1992, New York: United Nations.