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Research Article

Developing a Model for Sustainability Assessment in LARG Supply Chains using System Dynamics

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Abstract

Due to the growing global pressures for industries to become more sustainable, organizations are forced to implement new management practices at all organizational levels to achieve sustainability in the supply chain. New management practices should be measured in terms of assessing the sustainability performance. The purpose of this paper is to provide a model for assessing the sustainability performance of lean, agile, resilient, and green (LARG) supply chain management practices in the automotive supply chain using the system dynamics approach. In this paper, LARG supply chain management practices were identified and were prioritized using fuzzy DEMATEL and fuzzy analytic network process. The findings show that scenarios of improvement in the implementation of total quality management, just in time, flexible transportation and combined scenario (just in time and long-term relationships with suppliers) will lead to a more sustainable supply chain. The results of these scenarios show improvement of sustainability in the supply chain. Also the results show that lean strategy is a very important for achieving sustainability in the supply chain.

Keywords : Sustainability; Lean agile resilient and green (LARG); Supply Chain Management; System Dynamics; Fuzzy DEMATEL; Fuzzy Analytic Network Process.

1 Introduction

In response to growing concerns about the environmental and social impacts of supply chains, various stakeholders such as government legislators, consumers, NGOs, the media, and community activists are putting pressure on organizations to reduce the harmful impacts in their supply chains [1]. Sustainability creates balance between economic, social and environmental goals [2], which plays a critical role in the long - term success of the supply chain [3]. The adoption of sustainability principles brings benefits that go beyond the social and environmental areas and also generating improvement on the economic value of the organization [4]. Many global companies have begun to integrate sustainability principles into their supply chains [5]. Business sustainability is adopting strategies and activities that

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meet the needs of companies and stakeholders while protecting, sustaining and enhancing the human and natural resources that will be needed in the future [6]. Sustainability is considered a business and investment strategy that seeks to use the best business practices to meet and balance the needs of current and future stakeholders [7]. Therefore, new business strategies should be used to meet the needs of company [8]. It is necessary to implement management practices that not only promote company and overall supply chain (SC) performance, but also that focus on social, economic and environmental concerns [9]. Among the different paradigms of supply chain management, LARG paradigms ensure sustainability in the supply chain. Ruiz-Benitez, López and Juan C. Real [10] stated that lean practices help to improve sustainability. Azevedo et al., [11] considered lean and green practices as very important columns of sustainable development of businesses. Azevedo et al., [8] stated that agile and resilient practices have an impact on sustainability and promote sustainability performance. Simultaneous integration of LARG paradigms in supply chain management help supply chains to become more ef?cient, streamlined and sustainable [12]. LARG paradigms are accepted to improve supply chain performance. Therefore, in spite of such literature in the supply chain, this paper tries to integrate the LARG paradigms. Putting together the LARG paradigms could be resulted to a model that benefits from their synergies and by overlapping these paradigms with each other can reduce their weaknesses and then this study provide a model for assessing the performance of LARG supply chain management practices. The Triple bottom line (TBL) accounts for three pillars (economic, environmental and social) as the base of successful sustainable development [13], so it can be used as a metric to assess the sustainability performance of LARG practices. An assessment that includes sustainability aspects is very different from traditional and business-oriented evaluations [14]. Performance assessment of LARG supply chain management practices is extremely complex and challenging. The purpose of this paper is to provide a model for assessing the sustainability performance of LARG supply chain management practices in the automotive industry using a system dynamics approach that deals with dynamic and multi-dimensional features. The application of system dynamics in the field of sustainable studies is relatively new [14]. The integration of the dynamic system and the three dimensions of sustainability indicate dynamic interaction among the three dimensions of economic, social and environmental and LARG supply chain practices. The model presented in this paper allows managers and decision makers to assess and monitor the results obtained from implementing supply chain management practices and also help to identify areas for improvement in the supply chain.

The structure of this paper is as follows: In the second section, the literature is reviewed and discussed. In the third section, the research methodology is fully elaborated. Fourth section, describes data analysis and research findings, including prioritizing and integrating LARG supply chain management practices, dynamic hypotheses, causal-loop diagram, stock and flow diagram, validation and test of scenarios and finally, conclusions and suggestions are presented in section 5.

2 Literature Review

Orji & Liu, [14] have studied the dynamic behavior of key drivers of innovation-led lean approaches to achieve sustainability in manufacturing supply chain. Their study employed fuzzy logic and Fuzzy TOPSIS to prioritize the key drivers of innovation-led lean approaches. Then, a system dynamics model to examine the dynamics of lean approach and their impact on sustainable performance has been presented in the manufacturing supply chain. The results showed that dynamic behavior of “government regulations” and “conducive working conditions” affect sustainability, and “Cash availability” and “Fundamental knowledge” have no significant effect on sustainable performance.

Shamsuddoha [15] presented integrated supply chain model for sustainable production. He considered the supply chain and sustainability dimensions simultaneously and used the dynamics system to simulate the supply chain model. He stated that it can solve existing problems in the supply chain by obtaining economic, social and environmental benefits that is more sustainable than current practices. The findings showed that supply chain integration can ensure economic, social and environmental sustainability along with the structured production process.

Orji & Wei [16] integrated fuzzy logic and the system's dynamic approach to choose a sustainable supplier. They provided a new model for integrating information on the supplier's behavior in a fuzzy environment with a dynamics system modeling technique that results a reliable and responsive support system. The supplier's behavior has been achieved according to the sustainability criteria through the interview and has been simulated in VENSIM software to choose a sustainable supplier. Their results show that an increase in the rate of investment in sustainability by the different suppliers causes an exponential increase in total sustainability performance of the suppliers.

Chardine-Baumann & Botta-Genoulaz [17] proposed a framework for describing the sustainable performance characteristics and an analytical model for evaluating the performance of supply chain practices. The analytical assessment model is based on the relationships between a supply chain management practice and the three fields of sustainable development. She states that practitioners can easily use the proposed framework for highlighting SCM practices that impact sustainable performance more positively, depending on their objectives.

Kafa, Hani, & El Mhamedi [18] developed an analytical model for measuring sustainability performance for green supply chain management. The purpose of presenting the analytical model was to investigate the effect of green practices on sustainability performance in supply chain. Selected green supply chain management practices include green purchases, green design, green production, green distribution and reverse logistics. Of course, the main focus of this paper is the emphasis on environmental issues. They stated that this analytical model is the first step towards providing a comprehensive perspective that explains the relationship between green supply chain management practices and sustainability performance.

Safaei Ghadikilai & GholamReza Tababar [53] provided a framework for assessing the sustainability of food supply chain using a fuzzy analysis network process. Delphi method has been used to localize and validate research criteria. Their findings show that physical, psychological, and social health of employees and greenhouse gases are the most important criteria for achieving a sustainable supply chain. They stated that they can use this framework to evaluate different parts of the food supply chain and measure sustainability.

Review of literature shows that the previous studies often focus on providing a framework or an analytical model for the evaluation of sustainability performance and studies have focused on the dynamics of system in a supply chain with an emphasis on a paradigm and the form of integrating of several paradigms is not simulated. In this research, in addition to the integration of LARG paradigms, the mathematical modeling technique (dynamics of system approach) has been used to assess the sustainability performance of LARG supply chain practices.

3 Research Methodology

The present research is a practical one in terms of objective and is descriptive-analytical in terms of method. This research has been carried out in two steps. The first step is to integrate the LARG paradigms which the LARG supply chain management practices have been prioritized through the fuzzy DEMATEL and the fuzzy analytical network process methods. Experts' judgments have been used to extract the importance, weights and dependence between the criteria. In this step, fifteen questionnaires were completed and collected. The second step is to provide a model for assessing the performance of LARG supply chain management practices using system dynamics approach. Experts' judgments have been used to determine the relationship between sustainability criteria and LARG supply chain management practices. The statistical population in this study is composed of experts and managers of the automotive industry including auto part supplier, Supplying Automotive Parts Company (SAPCO) and manufacturer (Iran KHODRO). In this step, 30 questionnaires were completed and collected. Historical data was extracted through correspondence with the managers of the relevant units in the 2017 and 2018.

Due to the complexity inherent of the behavior of LARG supply chain management practices and sustainability criteria, one-dimensional and linear calculations cannot provide valid results. The dynamics of LARG supply chain management practices and their influence on sustainable performance in the manufacturing supply chain have nonlinear relationships and are dependent. In this study, system dynamics approach has been used Because of the complexity of the supply chain. System Dynamics is a methodology and mathematical modeling technique for framing, understanding and discussing complex issues and problems [15]. Therefore, the proposed approach involves system dynamics and three sustainability dimensions (economic, environmental and social) which is used to measure performance in LARG supply chain management.

3.1 Modeling steps

First, the problem is precisely identified and defined. By accurately defining the problem, it can be explained why particular behavior is manifested by the system. In the second step, dynamic hypotheses are presented from the problem, and the overall structure of the model is formed in the form of causal -loop diagram, which is the basis for providing stock and flow diagram. In the third step, the mathematical relationships between the variables and the initial values are obtained through the data collection, and they are formulated through VENSIM software. In step four, several tests are conducted to ensure the validity of the model and in the final step, scenarios have been designed to improve the performance of the model and the results obtained have been analyzed.

4 Data analysis and findings

Step 1: Integration of LARG paradigms using fuzzy DEMATEL and fuzzy analytic network process (ANP)
Fuzzy analysis network Process has been used to determine the weight of the criteria and sub-criteria of the model. The steps to the analysis are as follows:

Prioritizing the main criteria based on the goal through a pairwise comparisons
To perform analysis network Process, first, the main criteria based on goal are compared as pair-wise. There are four main criteria, therefore, six pairwise comparisons are carried out from the expert's point of view. In this method, firstly, the experts' views are gathered with Saaty 1-9 scale and then fuzzification is done. In order to aggregate the experts' judgments using fuzzy analytic network process, the geometric mean has been used. After the formation of pairwise comparisons matrix, the fuzzy sum of each row is computed. To normalize the preferences of each criterion, the sum of the values of criterion must be divided into the sum of all the preferences (column elements). Since the values are fuzzy, so the fuzzy sum of each row is multiplied by the inverse of the sum. Each of the obtained values are the fuzzy and normalized weight that they are related to the main criteria. In the final step, the defuzzification of the values is obtained and the calculations of the crisp number is done. Table 1 shows the weight of the main criteria (LARG paradigms).

Prioritizing each of the sub-criteria by pairwise comparisons
In the second step of fuzzy analysis network process technique, the sub-criteria related to each criterion (LARG practices) are compared in form of paired. After obtaining the matrix of pairwise comparisons for sub-criteria related to each criterion, the fuzzy sum of each row is computed. In the final step, the defuzzification of the values is obtained and the calculations of the crisp number is done.
The Consistency Ratio of the comparisons in resilient, lean, agile and green paradigms is 0.013, 0.021, 0.081 and 0.006 respectively, that all of them are less than 0.1. Therefore, these comparisons can be trusted.

Identifying the internal relations between the main criteria and sub-criteria

Table 1: The weight of the main criteria

Paradigms	Weight
Resilient	.428
Lean	.246
Agile	.164
Green	.163

Table 2: The weight of the sub-criteria

Resilient sub-criteria	Weight
Flexible transportation	.219
Strategic stock	.293
Lead time reduction	.224
Flexible sourcing	.180
Developing visibility to a clear view of downstream inventories and demand conditions	.035
Sourcing strategies to allow switching of suppliers	.048
Lean sub-criteria	weight
Customer relationships	.185
Just-in-time	.286
Supplier relationships/long-term business relationship	.242
Total quality management	.236
Setup time reduction	.0225
Lot size reduction	.0278
Agile sub-criteria	weight
Centralized and collaborative planning	.165
Ability to change delivery times of supplier's order	.216
To Speed in improving responsiveness to changing market needs	.1606
To speed in improving customer service	.132
To increase frequencies of new product introductions	.1610
To reduce development cycle time	.1611
Green sub-criteria	Weight
ISO 14001 certification	.1617
To reduce energy consumption	.194
Reverse logistics	.1623
To reuse/recycling materials and packaging	.141
Eco-friendly packaging	.154
Environmental collaboration with suppliers	.189

with the fuzzy DEMATEL technique.
The next step is to calculate the internal relations of the identified indicators. In this way, the matrix of the internal relations of the main criteria W22 and the matrix of internal relations of the sub-criteria W33 will be obtained. In order to reflect the internal relations between the main criteria and the sub-criteria, the fuzzy DEMATEL technique is used. Table 3 shows the fuzzy spectrum.

Steps to fuzzy DEMATEL technique:

1. A direct relation matrix (M)
2. A normalized direct relation matrix
3. The total relation matrix
4. Defuzzified total-relation matrix
5. Network Relation Map (NRM)

Diagram of internal relationships sub-criteria is shown in Figure 1.

Calculation of the initial super matrix, weighted super matrix and the limit super

Table 3: Fuzzy spectrum and DEMATEL technique [19]

Linguistic variable	Quantity equivalent	Fuzzy Quantity equivalent		
		l	m	u
No effect	0	0	0.1	0.3
Low effect	1	0.1	0.3	0.5
Effective	2	0.3	0.5	0.7
Much effect	3	0.5	0.7	0.9
Very much effect	4	0.7	0.9	1

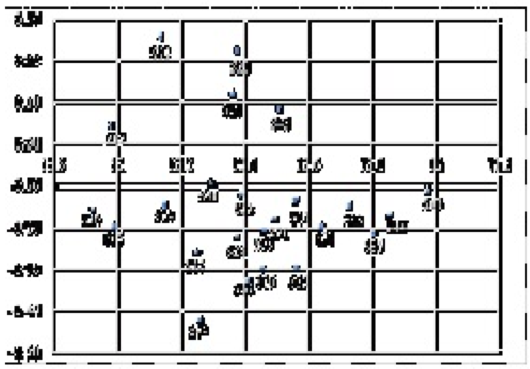

Figure 1: Diagram of internal relationships sub-criteria.

Figure 2: Strategic stock in SAPCO.

matrix

To determine the final weight, the output of comparing the main criteria and sub criteria and the internal relations between the criteria and the sub-criteria is presented in a super-matrix .This super matrix is called initial super matrix. The initial super matrix is as follows:

$$W=\begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & W_{33} \end{bmatrix}$$

In this super matrix, the W21 vector shows the importance of each of the main criteria based on the goal. The W22 vector shows a pairwise comparison of the relationships between the main paradigms derived from the DEMATEL technique. The W32 vector indicates the importance of each sub-criterion in its own cluster. The W33 vector indicates a pairwise comparison of the relationships between the sub-criteria derived from the DEMATEL technique. According to the calculations performed in steps 1 to 4, initial super matrix has been obtained. In the next step, using the concept of normalization, the unweighted super matrix is inverted into weighted super matrix. The unweighted super matrix contains the local priorities derived from the pairwise comparisons. All the local priority information can be read directly from the unweighted super matrix. The weighted super matrix is obtained by multiplying all the elements in a component of the unweighted super matrix by the corresponding cluster weight matrix, which makes each column there in add up to 1. The column vectors of the cluster weight matrix could be determined from the eigenvectors of the pairwise comparison of clusters. The limit super matrix is obtained by raising the weighted super matrix to powers by multiplying it with itself. When the column of numbers is the same for every column, the limit matrix has been reached and the matrix multiplication process is halted,

$$w=\left(\frac{1}{N}\right)\sum_{K=1}^{N} W^{K}$$

Where W is the limit super matrix, W is the weighted super matrix, N indicates the sequence, and k is the exponent determined by iteration. After a limit super matrix is calculated, this process is repeated for other networks. Super Deci-

Table 4: Final priority of LARG practices.

Sub-criteria	Sub-criteria symbol	Final weight	Final priority
ISO 14001 certification	S11	0405	13
Energy consumption reduction	S12	0.0481	8
Reverse logistics	S13	0.0405	14
To reuse/recycling materials and packaging	S14	0.0353	19
Eco-friendly packaging	S15	0.0385	18
Environmental collaboration with suppliers	S16	0.0473	9
Customer relationships	S21	0.0462	10
Just-in-time	S22	0.0714	2
Supplier relationships/long-term business relationship	S23	0.0604	3
Total quality management	S24	0.0589	4
Setup time reduction	S25	0.0056	24
Lot size reduction	S26	0.0069	23
Flexible transportation	S31	0.0549	7
Strategic stock	S32	0.0734	1
Lead time reduction	S33	0.0561	6
Flexible sourcing	S34	0.0451	11
Developing visibility to a clear view of downstream inventories and demand conditions	S35	0.008	22
Sourcing strategies to allow switching of suppliers	S36	0.012	21
Centralized and collaborative planning	S41	0.0428	12
Ability to change delivery times of supplier's order	S42	0.0578	5
To Speed in improving responsiveness to changing market needs	S43	0.0395	15
To speed in improving customer service	S44	0.0323	20
To reduce development cycle time	S45	0.0388	16
To increase frequencies of new product introductions	S46	0.0388	17

sions software was used to process the data. The priorities of elements are found in the corresponding columns in the limit super matrices. [20] Thus, the final priority of LARG practices are shown in Table 4.
Second step: presentation of a model of sustainability performance assessment of LARG supply chain management practices using system dynamics

4.1 Dynamic problem

The final product of automotive companies is the result assembly of a certain number of different parts. Automobile is one of the products that its production would be stopped if there were not even one part. Sanctions and lack of cooperation by suppliers, especially foreign suppliers, can lead to shortage of inventory. Lack of inventory is one of the most important factors in creating a crisis in the production processes. The automotive supply chain is vulnerable when is faced

Figure 3: Hypothesis of strategic stock

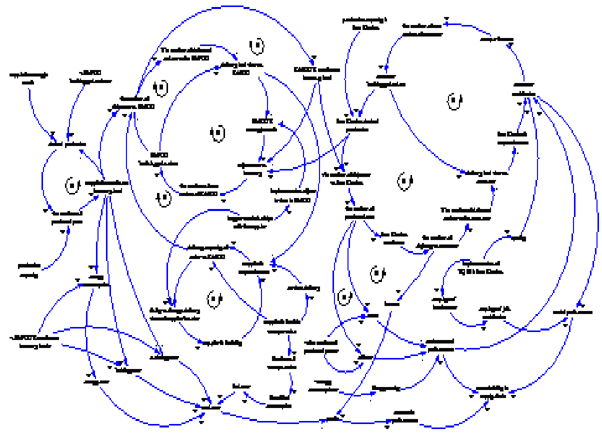

Figure 5: Causal-loop diagram

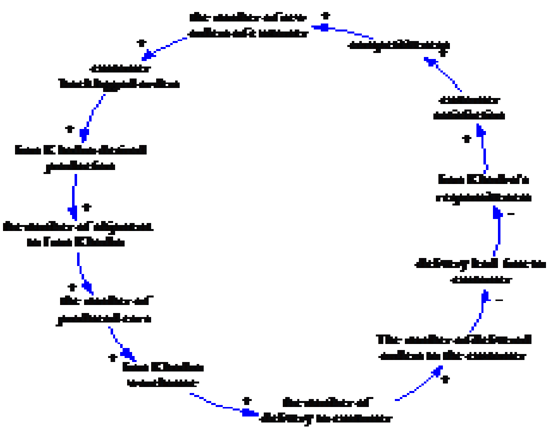

Figure 4: Hypothesis of lead time

with a shortage of parts. This problem leading to an increased production of defective cars, delay in delivery of final products, customer dissatisfaction, a reduced sale, a reduced profit and a stopped production line. The role of inventory as a safety stock against uncertainty is obvious. The inventory level is determined with considering the uncertainty of supply and demand. Therefore, keeping strategic stock is important for supply chain in this situation. The level of strategic stock will have a significant impact on operating costs in the future. Excessive inventory will result in a highly holding costs and energy consumption costs. Profitability is reduced with an increase in costs. This means that keeping excessive inventory will lead to decrease in economic performance. Strategic stock in SAPCO is shown in Fig 2.

4.2 Dynamic hypothesis

H1: Strategic stock

Just in time is one of the most important practice in lean supply chain management. This practice carries out frequent shipping with low volumes. Due to in this policy, inventory is low or not, inventory shortages may lead to stop production at the time of the disruption. Companies, especially suppliers cannot be responsible for the disruptions. It can be said that this policy will make the supply chain vulnerable. Therefore, companies need to use a strategic stock to ensure the flow of materials at a time of disruption to bridge the risks associated with inventory. Strategic stock and lead time reduction are used to protect against amount of demand, time of demand, time of production and amount of production through reduction in lead time. The lead time is related to the strategic stock level. Strategic stock is increased by increasing lead time. On the other hand the number of new orders of SAPCO, the number of shipment to SAPCO and the number of delivered orders to the SAPCO are decreased and ultimately the lead time is increased.

H 2: Lead time reduction

Lead time reduction creates a competitive advantage and helps to achieve the internal supply chain optimization and sustainability. Flexible production is required a quick delivery of parts by suppliers. Crisis will created in the supply network, if the lead time is long and ultimately, the probability of supply chain vulnerability is increased against disruptions. Lead time reduction is the new global strategy which, increase responsiveness, competitiveness and customer satisfaction. The number of new orders of customer is increased by increasing competitiveness and also sale and profit are increased. The increase in the number of new orders of customer leads to increase in Iran Khodro desired production, the number of shipment to Iran Khodro, the number of produced cars, Iran Khodro warehouse and the number of delivery to customer and finally delivery lead time to customer is decreased.

4.3 Causal-loop diagram

Tables 5 illustrate the variables used in the model for the automotive supply chain.

To illustrate the causal relationships between the variables and the feedback structure of the system, the best tool is to use of the causal-loop diagram. This chart has 6 negative feedback loops and 4 positive feedback loops. Figure 5 shows the causal relationships between LARG supply chain management practices and sustainability criteria.

4.4 Model boundary chart

A model boundary chart summarizes the scope of the model by listing which key variables are included endogenously, which are exogenous, and which are excluded from the model. Table 6 shows a model boundary diagram for automotive supply chain.

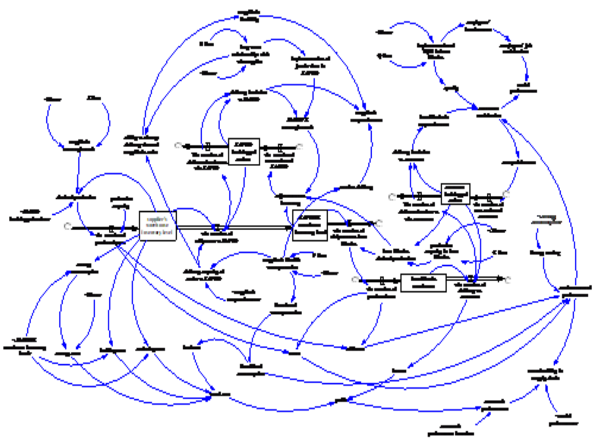

Figure 6: Stock and flow diagram

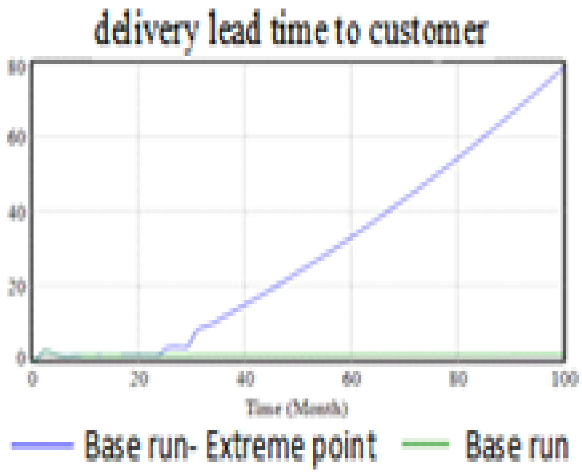

Figure 7: Extreme Condition Test related to the variables of the number of vehicle production and delivery lead time to customer

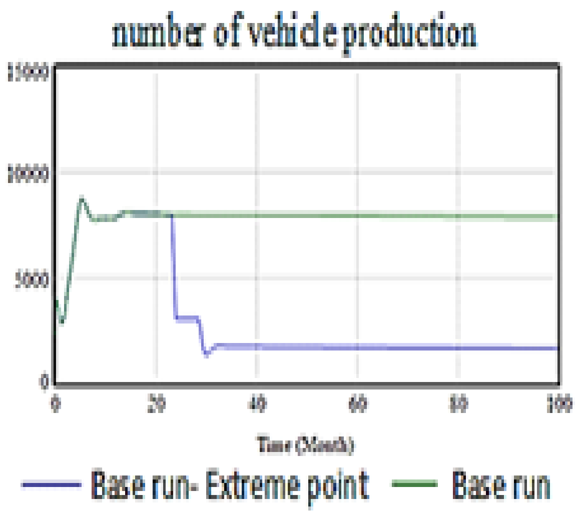

Figure 8: Behavior Reproduction test related to the variables of the number of shipment to SAPCO and the number of delivery to the customer

4.5 Stock and flow diagram

This diagram shows how the variables of the system interact with each other. The used variables in this model are divided into three groups: A) state variables: A state variable is a variable that accumulates or integrates a flow over consecutive time periods [46], and These variables increases or decreases over time by the rate variable, such as the supplier warehouse inventory level, SAPCO

Table 5: LARG supply chain management practices and sustainability criteria.

	LARG supply chain management practices	Source
1	strategic stock	[8], [12], [21], [22]
2	Just in time	[8], [23], [24],[25],[26],[27]
3	supplier relationships/long -term business relationship	[8], [9], [28], [29]
4	total quality management	[8], [9], [23], [25]-[27], [29]
5	ability to change delivery times of supplier's order	[8], [12], [30]
6	lead time reduction	[8], [9], [12], [21], [22], [31]
7	flexible transportation	[8], [9], [12], [22], [27]
8	energy consumption reduction	[8], [32], [33]
	sustainability criteria	source
1	Cost (ordering cost, holding cost, energy cost, fuel cost)	[34]–[36]
2	profit	[37]
3	Responsiveness	[38], [39]
4	flexibility	[35], [36], [38]–[40]
5	quality	[18], [35], [36], [38], [39], [41], [42]
6	On time delivery	[36], [40], [41]
7	Customer satisfaction	[34], [37], [40], [42]
8	competitiveness	[34], [43]
9	employees' involvement	[44]
10	employees' job satisfaction	[18], [37], [40]
11	energy consumption	[27], [34], [37], [43], [45]
12	fuel consumption	[40]
13	income	Experts opinion
14	effluent	Experts opinion
15	waste	Experts opinion
16	Energy saving	Experts opinion

warehouse inventory level, Iran Khodro's final product warehouse, SAPCO backlogged orders, customer backlogged orders. B) Rate variables: A Rate Variable is a variable that represents a flow during a given time period [46], such as: the number of parts produced, the number of shipment to SAPCO, the number of shipment to Iran Khodro, the number of vehicles produced, the number of delivery to the customer, the number of new orders of SAPCO, the number of orders delivered to SAPCO, the number of new customer orders, the number of orders delivered to the customer. C) Auxiliary variables: An Auxiliary variable is a variable that is used to identify or clarify rate variables or other auxiliary variables [46]. Table 5 introduces the variables. This model has 65 mathematical equations. Figure 6 shows the stock and flow diagram of the model.

Table 6: Model boundary chart for automotive supply chain.

Endogenous		Exogenous	Excluded
Employees' job satisfaction	Quality	Implementation of TQM in Iran Khodro	Production technology
Delivery capacity of order to SAPCO	SAPCO'S warehouse inventory level	Long-term relationships with the supplier	Human resources
Desired production	The number of produced cars	Supplier's strategic stock	Research and development
Energy consumption	Iran Khodro warehouse	Production capacity	Greenhouse gas emissions
Supplier's warehouse inventory level	The number of delivery to customer	Supplier's flexible transportation	Productivity
delivery lead time to customer	Iran Khodro desired production	Production capacity in Iran Khodro	Business environment Shortage cost
Holding cost	The number of new orders of SAPCO		Efficiency Sale
Ordering cost	Fuel cost		
SAPCO backlogged orders	The number of shipment to Iran Khodro		
The number of shipment to SAPCO	Employees' involvement		
Total cost	Supplier's flexibility		
Fossil fuel consumption	Social performance		
Customer satisfaction	Number of transportation		
Delivery lead time to SAPCO	The number of produced parts		
The number of delivered orders to the SAPCO	Iran Khodro's responsiveness		
On time delivery	Competitiveness		
Implementation of just in time in SAPCO	The number of new orders of customer		
SAPCO'S strategic stock	Customer backlogged orders		
Supplier's responsiveness	The number of delivered orders to the customer		
Profit	Energy cost		
Sustainability in supply chain	Ability to change delivery times of supplier's order		
waste	Energy saving		
Effluent	Environmental performance		
Income	Economic performance		

4.6 Validation

One of the most important steps in modeling is validation of the model. Since the system dynamic usually represents the actual operation of real systems in some aspects, Validation of the model is very necessary for confirming the acceptance of the model [47]. To ensure the validity of the model, the following tests were carried out and the results are as follows:

- **1.** Dimensional consistency Test: This test is done to determine the units of measure for each variable and coordinate them with reality.

- **2.** Structure Assessment Test: In this research, using the experts' opinions in the automotive supply chain, the structure of the model was examined and the structural validity of the model was confirmed.

- **3.** Extreme Condition Test: Models should be robust in extreme conditions. Robustness under extreme condition means the model should behave in a realistic fashion no matter how extreme the inputs or policies imposed on it may be. For example, Iran Khodro production capacity will be reduced by 80% in the 24 month. As shown in figure 7, the number of car production has dropped dramatically and delivery lead time to customer has risen extremely.

- **4.** Behavior reproduction test: The purpose of a behavior reproduction test is to compare simulation results with real data to ensure that the behavior of the model is accurate. In this case, simulated behavior is reproduced for the pattern to compare with real data. As shown in figure 8, real data and simulation of the number of delivery to the customer and the number of shipment to SAPCO in the years 2017 and 2018 are shown. These graphs show the behavior of variables that are well simulated by the model.

4.7 Error analysis of the model

In addition to the behavior reproduction test, the error test index is also used in order to ensure simulation results. The error rate of key variables is calculated based on the following methods.

Root Mean Square Percent Error (RMSPE)

Based on this method, whatever the difference between real and simulated data is less, further simulation results can be trusted. The error rate in this method is calculated according to equation as follows,

$$RMSPE=\sqrt{\frac{1}{\theta}\sum_{i=1}^{\theta}\left(\frac{y^s_{T+i}-y^a_{T+i}}{y^a_{T+i}}\right)^2}\times 100$$

In this equation y^s_{T+i} is the result of the pattern variable simulation, y^a_{T+i} is the real data and θ is the number of observation. Whatever the closer R is to zero, meaning fewer errors and whatever the closer R is to100, meaning a higher error.

Inequity Theils

Calculation of Inequity Theils is another method of measuring the error rate of simulated data from real data. The value v is between zero and one. If V equal to zero, it means that the predicted values in the pattern are equal to the real value, and if V equal to 1, it means that the pattern performance is not suitable for evaluating the system actual behavior. The amount of this error is calculated according to equation as follows,

$$IT=\sqrt{\frac{\frac{1}{\theta}\sum_{i=1}^{\theta}\left(y^s_{T+i}-y^a_{T+i}\right)^2}{\frac{1}{\theta}\sum_{i=1}^{\theta}\left(y^s_{T+i}\right)^2+\frac{1}{\theta}\sum_{i=1}^{\theta}\left(y^a_{T+i}\right)^2}}$$

The results of the error calculation tests for the variables of the number of delivery to the customer and the number of shipment to SAPCO are shown in Table 7. The results of the tests show that the error rate in the considered variables is at an acceptable level.

4.8 Scenario analysis

First scenario: Improvement in implementation of total quality management

Total quality management is one of the LARG supply chain management practices that effects on supply chain sustainability. By implementing this scenario, employee participation and job satisfaction have increased dramatically, as well as increased product quality. In addition, customer satisfaction, competitiveness and the number of new orders have increased. With a 20 percent increase in implementation of total quality management, it was found that social performance had increased and did not affect economic performance and has improved environmental performance. But in general, it has improved sustainability in the supply chain .These findings are in line with Alharbi et al., [48] results. They state that total quality management has effect on sustainability. Govindan et al., [9] state that total quality management practice is a very important that lead to increase customer satisfaction, Findings obtained by Govindan et al., [9] confirm the

Table 7: Results of calculate the error rate.

IT	RMSPE	Variables
.0691	17.3835	the number of delivery to the customer
.0604	15.1159	the number of shipment to SAPCO

results of this investigation regarding with TQM.

Second scenario: Improvement in implementation of just in time

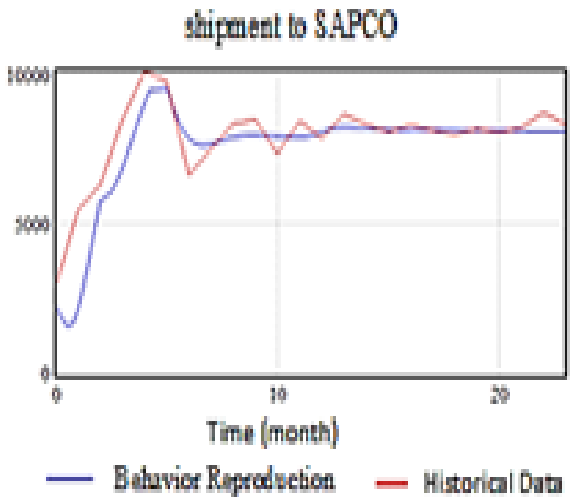

Figure 9: Sustainability and social performance in the supply chain after implementing an improvement scenario in TQM

Just in time is one of the LARG supply chain management practices that effects on supply chain sustainability. The behavior of the system shows that with a 30 percent increase in implementation of just in time, the strategic stock and inventory level of SAPCO warehouse have decreased significantly and with decrease in inventory level, holding costs, energy consumption, and total cost has been reduced. On the other hand, profit has been increased and has improved economic performance and social performance has been decreased due to decrease in inventory level and reduce in car production that has led to customer dissatisfaction, as well as environmental performance have been increased very little. Ultimately, the behavior of system indicates that Sustainability has been increased in the supply chain and Azevedo et al., [8] , Ruiz-Benitez et al., [10] state that JIT has a positive impact on economic performance. Pagell and wu [49] state that JIT has appositive impact on Sustainability in the supply chain and the finding of these researchers are in line with the results of this research.

Figure 10: Economic performance in the supply chain after implementing an improvement scenario in JIT

Third scenario: Improvement in implementation of flexible transportation

Flexible transportation is one of the LARG supply chain management practices that effects on supply chain sustainability. With a 20 percent increase in implementation of flexible transportation, the on time delivery and supplier's responsiveness have increased significantly and as well as the delivery capacity of order to SAPCO has been grown significantly. The ability to change delivery times of supplier's order and supplier's flexibility has also been affected by this scenario and it has improved the environmental performance. Economic and social performance have not been affected by the increase in flexible transportation due to inefficiency, customer dissatisfaction and low profitability in supply chain. Ultimately, the improvement of this practice in the supply chain has led to sustainability in supply chain. Govin-

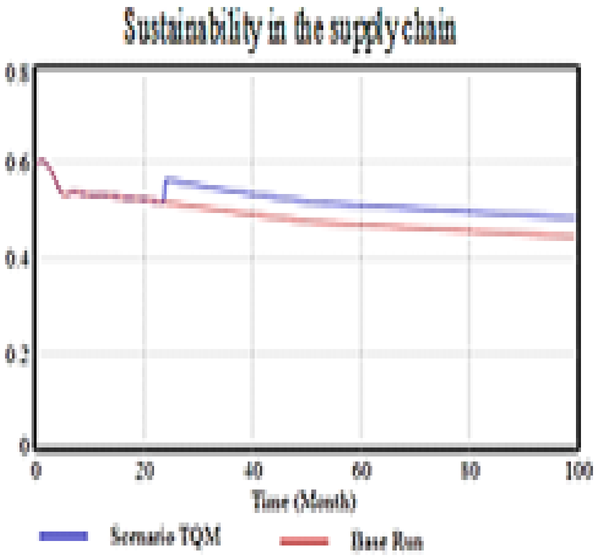

Figure 11: Sustainability and environmental performance in the supply chain after implementing an improvement scenario in flexible transportation

dan et al., [9] state that flexible transportation has a positive impact on environmental performance but has not impact on social performance. Findings obtained by Govindan et al., [9] confirm the results of this investigation regarding with flexible transportation.

Fourth scenario (combination): combine two scenarios of improvement in just in time and long-term relationships with suppliers.

In this scenario, the scenarios of improvement in just in time and increase in long-term relationships with suppliers are simultaneously performed on models to observe the effects of these two scenarios on model behavior. Model behavior with the implementation of a combined scenario shows that strategic stock has been dramatically decreased and supplier's responsiveness to meet the SAPCO orders has been increased enormously. With the implementation of combined scenario, the economic and environmental performance, compared with the separate scenario of just in time (JIT), has been improved considerably and finally, sustainability in the supply chain has been improved. Iranmanesh et al., [51] argue that relationships with suppliers have a significant impact on sustainability that finding of these researcher is in line with the results of this research.

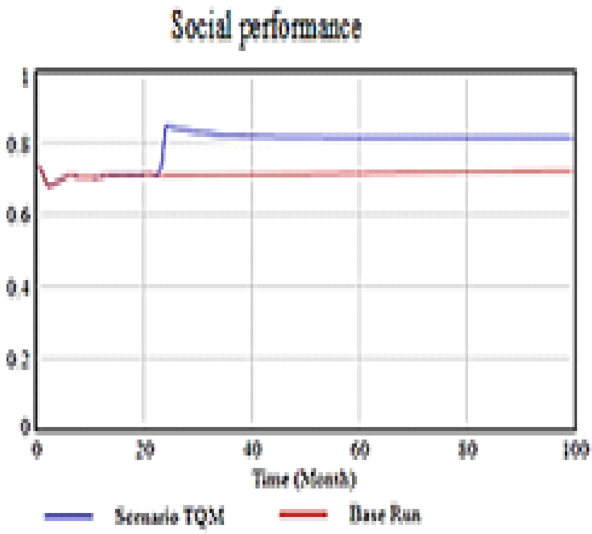

Figure 12: Sustainability and economic performance in the supply chain after the implementation of the combined scenario

5 Conclusions

Due to increased customer knowledge and ecological pressures from markets and various stakeholders, the manufacturing sector have emphasized the importance of sustainability in their supply chain [14]. Organizations are trying tough to perk up their sustainability through different strategies such as lean, agile, green and resilient to sustain their position in today's environment [52]. Therefore, the issue of sustainability in the supply chain has been become one of the important issues in today's business environment and plays a very important role in increasing competitive ability. In this paper, the automotive supply chain has been simulated to understand the dynamics of LARG supply chain management practices on sustainable performance over time using a dynamic of system approach. This research has contributed to the literature on LARG supply chain management practices and the adoption of strategies to achieve sustainability in the supply chain. In this research, LARG supply chain management practices and sustainability criteria related to the supply chain of automotive in Iran have been identified through literature reviews and interviews with experts. LARG supply chain management practices have been prioritized through fuzzy DEMATEL and fuzzy analysis network process, and an integrated approach in the form of LARG supply chain was presented. Based on the steps of the system's dynamic approach, after determining the dynamic hypothesis, causal relationships between the LARG practices and sustainability criteria were determined and then the stock and flow diagram was drawn up and Validation was carried out after the presentation of the model. Finally, the scenarios of improvement in TQM, JIT, flexible transportation and combined scenario (Improvement in JIT and long-term relationships with the supplier) were explained to improve the model's behavior, and after implementing the scenarios, the impact of these practices was observed on supply chain sustainability. The results obtained from the implementation of these scenarios indicate improvement of sustainability in the supply chain. The findings show that improvement of implementation of total quality management, just in time, flexible transportation and combined scenario (improvement of just in time and long-term relationships with the supplier) are suitable practices for supply chain sustainability. The results show that Lean strategy is a very important strategy for achievement of sustainability in the supply chain. Therefore, it can be argued that managers and decision makers can improve the implementation level of total quality management and just in time for increasing the level of sustainability in the supply chain.

Suggestions

In this research, 8 LARG supply chain management practices and 16 sustainability criteria related to the automotive supply chain have been used. Future researchers are recommended to expand sustainability criteria and LARG supply chain management practices and use other criteria and practices in their study. This research focused on automotive industry. Therefore, the results of this study cannot be generalized to other industries, so it is suggested that researchers should perform studies in this field in other manufacturing industries. In the model designed in this research, the supplier of the parts is considered at one level. It is suggested that suppliers will be added to the model from supplier of the raw materials (source), and it is suggested that the section of distribution of the car in the model be considered.

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