Advances in Industrial Engineering, Spring 2021, 55(2): 203-218
DOI: 10.22059/aie.2021.330673.1806

RESEARCH PAPER

Dynamic Analysis of Lean and Green Supply Chain Policies in Sustainability of CHOUKA Iran Wood & Paper Industries Inc.

Mohammad Ali Enayati Shiraz [a], Seyyed Abdolla Heydariyeh [b,*], Mohammad Ali Afshar Kazemi [a]

a. *Department of Industrial Administration, Central Tehran Branch, Islamic Azad University, Tehran, Iran.*
b. Department of Industrial Administration, Semnan Branch, Islamic Azad University, Semnan, Iran.

Received: 19 September 2021, Revised: 31 October 2021, Accepted: 02 November 2021

Abstract

Supply chain sustainability in economic systems and green supply chain management have widely attracted researchers' attention by raising awareness of environmental effects. On the other hand, the lean supply chain is another concept whose implementation in organizations is expected to result in improved sustainability in industries. This study aimed to analyze the policy-based roles of lean and green supply chain concepts in corporation sustainability by designing a system dynamics model of the supply chain in CHOUKA Iran Wood & Paper Industries Inc. To this end, after a review of the literature with collaborations from decision-makers and CHOUKA data, the system dynamics model was designed in Vensim, and the model was simulated in a 10-year horizon after validation. Considering the behavior of the variables and the Monte Carlo sensitivity analysis, the model was simulated in the horizon, the green supply chain policies, the lean supply chain management and CHOUKA's business profitability were designed and applied to the model both in separate and integrative manners, the results were compared, and the behaviors of the policies were analyzed. As for the findings of the model simulation, the selected combination of lean and green supply chain management policies, as well as CHOUKA's business profitability, was proposed as the best integrative sustainability policy for CHOUKA Iran Wood & Paper Industries supply chain management. The results generally indicated that simultaneous implementation of lean and green supply chain policies led to synergy in supply chain sustainability.

Keywords:
Green Supply Chain,
Supply Chain Sustainability,
System Dynamics,
CHOUKA Iran Wood & Paper Industries

Introduction

Supply chain sustainability topics have become increasingly informed in recent years [1]. Economic systems' supply chain management mitigates environmental and social impacts in meeting different shareholder expectations and risks involved in supply chain sustainability. Environmental concerns led to the development of the green supply chain management concept, and corporations and clients are attracted to methods helping environmental sustainability. In this regard, discussing green supply chain management and sustainability during production and gaining competitive advantage are of significant importance [2]. The green supply chain

* Corresponding author: (S.A. Heydariyeh)
Email: a.heidariyeh@semnaniau.ac.ir

takes into account the environmental aspects throughout the supply chain. Going green has become a must today [3]. Green supply chain management has widely attracted researchers by raising awareness on environmental impacts [4]. On the other hand, the lean supply chain is a concept whose implementation in organizations is expected to bring about improvements in sustainability in industries [5]. Several researchers have confirmed the positive and significant effect of the lean supply chain on green activities [6]. There is also evidence showing lean and green synergistic effect on the sustainable supply chain in Johansson and Sundin, and Besseris and Kremmydas, where it was emphasized that simultaneous implementation of lean and green led to synergy in supply chain sustainability and competitive advantage [7,8]. Few modeling approaches for sustainable supply chain management have recently received high attention in recent years. However, most sustainability models at large have analyzed systems, while intra-organizational and inter-organizational factors are more prominent in supply chain models [9]. As for Iran wood and paper industry as the main source of raw materials for producing paper using industrial forests of natural resources North of Iran, excessive exploitation of northern forests and the consequent environmental impacts represent a challenge immensely noted in recent years. Elseways, as one of the most established factories of the country in the wood and paper industry, CHOUKA Iran Wood & Paper Industry Inc. has experienced several crises, which have challenged the corporation's sustainability and market share when facing recent challenges in the country's wood and paper industry, including shortage of raw materials, lack of comprehensive and practical long-term plans, exhaustion of manufacturing machinery, shortage of financial sources, and unexpected incidents in supplying the required currency. Given the alignment of lean and green supply chain approaches in the corporation's supply chain sustainability, this study designed a system dynamics model of the supply chain in CHOUKA Iran Wood & Paper Industries Inc. and aimed to analyze the policy-based roles of the lean and green supply chain concepts in the corporation sustainability in order to gain competitive advantage. Accordingly, after a review of the literature on sustainable supply chain management, lean supply chain management, and green supply chain management, a system dynamics model of the paper supply chain was designed, and the dynamics of the sustainable supply chain of Iran Wood & Paper Industries Inc. was analyzed taking lean and green supply chain approaches.

Literature review

Sustainable supply chain management

As economic systems' supply chain is manageable with respect to environmental and social impacts to meet various shareholder expectations and mitigate risks involved in sustainability, the concept of sustainable supply chain has gained significance [9]. Sustainable supply chain management is an important organizational philosophy needed for achieving profitability by mitigating risks stemming from environmental impacts and simultaneously improving economic and social factors [10].

Green supply chain

The green supply chain takes into account the environmental considerations throughout the supply. These considerations include the following: Product design, selection and supply, raw materials, development and production, transport and distribution processes, and waste and recycling management. Several indicators have been recommended by researchers: environmental characteristics of suppliers, environmentally induced collaborations, cooperation in green packaging, reuse-oriented designs, and green purchasing [11]. Product

design is aimed to reduce materials and energy use and help recycling, where the convergence of economic and environmental aspects in supply chain sustainability is emphasized [12].

Lean supply chain

The lean supply chain is a concept whose implementation in organizations is expected to bring about improvements in sustainability in industries [5]. In general, supplier's strategic collaboration, customer relationship, information sharing, and internal and external lean practices are considered as the lean supply chain components, the internal lean practices concern using methods of eliminating waste, cost, excess time, etc. in the production system [13], and the external lean practices focus on suppliers and customers, including supplier's strategic collaboration and building a long-term relationship between the organization and the supplier [14]. Supplier's collaboration, in turn, requires a primary supplier, collaboration in developing a new product, and sharing of the technological capabilities of the supplier [15], and customer relationship is a business strategy for mutual management with customers in order to optimize values and achieve long-term customer satisfaction [16]. Information sharing with beneficiaries also refers to the corporation's capability in sharing knowledge with supply chain's partners using effective and efficient methods [1]. In the literature review, extensive research in three areas of the literature and research on the paper industry in the country was considered. With respect to the green supply chain, numerous studies are found investigating the effective factors in green management and quantitative and systems modeling. Reche carried out an extensive bibliographic study on the process of developing integrated products and green supply chain management as for partnerships, limitations, and applications including green purchasing, green distribution, and green production issues [2]. Song designed the green supply chain dynamics model based on technology, energy, environment, and economy subsystems, and proposed optimized policies for realizing economic and environmental goals [17]. Zhou et al. studied the role and status of the government's regulations and policies and decision-making in the green supply chain by designing a model based on the game theory between suppliers, manufacturers, and governments, and analyzed sustainable strategies [18]. Wang et al. conducted a research work, where they considered green supply chain and performance sustainability of manufacturing industries companies in China using hierarchical multiple regression and demonstrated that the green supply chain management had a positive effect on the companies' performance sustainability [19]. Yousef Abadi et al. designed the sustainable facility relocation model in agriculture systems using the GIS and best–worst method [20]. Tafakkori et al. addressed sustainable generalized refueling station location problems under uncertainty [21]. Bappy et al. proposed a framework to assess the environmental criteria for sustainability in select industries in Bangladesh [22].

Regarding lean supply chain, Khorasani et al. addressed lean supply chain management in health care and reported a list of lean practices [23]. Zhou and Li addressed the effect of supply chain practices and quality management on company performance and emphasized the implementation of the lean supply chain practices [24]. Izadyar et al. proposed an evaluation model of the performance of large supply chain management methods in the automotive supply chain using the system dynamics approach and indicated that improvement scenarios in executing comprehensive quality management, timely production, and flexible transportation lead to further sustainability in the supply chain [25]. In an attempt to find out if lean could lead to green in a study, Gupta et al. assessed production processes by using system dynamics modeling in the tire industry [26] and demonstrated that residue and waste management have considerable and subsequent effects in improving green and lean performances. Tafreshi et al. designed lean/green supply chain and company sustainability models by modeling structural equations in food industries and indicated that the green supply chain has a positive and

significant effect on all economic, social, environmental, and governance dimensions of company sustainability [5]. The present study proposes that company sustainability indicators' managers be monitored in order to explore the current sustainability state in companies, and efforts be made to implement and apply the lean-green supply chain .In addition to the studies conducted in three areas of literature, Iran wood and paper industry research was investigated at length. Evaluating the challenges involved in the paper industry in the country, Bahmani et al. identified the large gap between universities and industrial centers and manufacturing machinery exhaustion as the most important ones [27]. Ramezanian et al. identified the complexity of the paper supply chain based on the theory of constraints (TOC) [28]. Zadmirzaie et al. determined relative efficiency in the paper industry by using data envelopment analysis (DEA) [29]. The literature review suggests that supply chain system dynamics have not been considered the concepts of green and lean supply chains less in an integrated manner. On the other hand, Less has been done on the supply chain of Iran's wood and paper industries, and modeling the system dynamics of the sustainability system of Iran wood and paper industries supply chain is among the innovations of the present study.

Research methodology

System dynamics is known and applied for modeling complex systems with the aim of modeling systems and identifying policies. The system dynamics methodology involves steps, the first of which is problem identification and definition (problem framing), which represents the most important step in the modeling. The second step is the identification of dynamic hypotheses. When the problem is defined and an appropriate time horizon is determined for it, modelers propose hypotheses, called dynamic hypotheses. The third step involves the following: One: A conceptual model (causal loop diagram). After identification of dynamic hypotheses, the development of the conceptual model (causal loop diagram) states the relationship between the phenomena. Two: Drawing the model's flow chart. The fourth step is model simulation and validation. The fifth step is a provision of different scenario definitions, and the selection and implementation of the appropriate solution [30]. By applying lean and green supply chain policies in modeling, the behavior of the model's key variables was examined and the best supply chain management sustainability policies in Iran wood and paper industries were proposed. The model data were collected based on the documents and reports of Iran Wood & Paper Industries Inc. and collaborations from the decision-makers of this corporation, and the model was simulated with Vensim DSS and Motne Carlo sensitivity analysis.

Analysis of research findings

System Dynamics model

Since this model was searching for paper supply chain management policies, the subsystems were designed on the basis of the paper industry supply chain sustainability and lean and green supply chain processes. Fig. 1 shows the interactions between the model components and the paper supply chain management model subsystems.

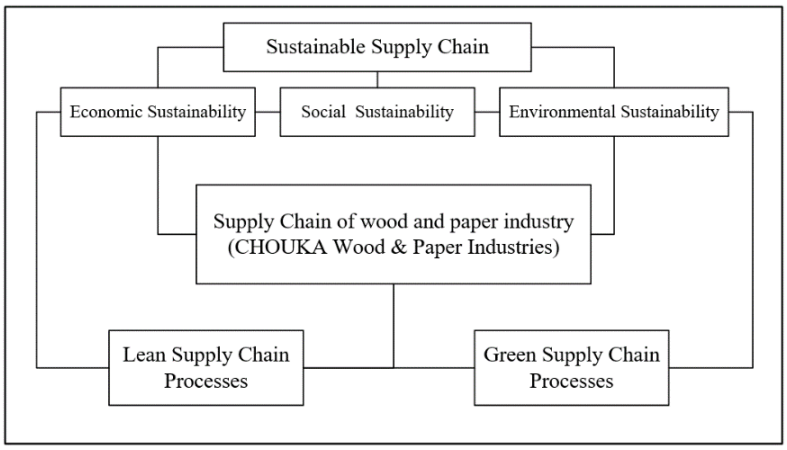

Fig. 1. Paper supply chain management model subsystems and interaction between model components

By considering the identified subsystems, using the research literature and background, and also seeking the paper industry expert opinion, effective variables, i.e. endogenous and exogenous variables, as well as variables that do not play a significant role in model dynamics, were identified for each of those subsystems, and the causal loop diagram was drawn. Research literature and background, as well as the paper industry expert opinion and the behavior of reference variables and basic behavior patterns, were used to determine the causal relations of the problem.

CHOUKA Iran Wood & Paper Industries Inc. supply chain sustainability model was designed according to the subsystems of raw materials supply, financial resource flow and research and development investment, factory machinery and equipment, expert human resources, lean supply chain process, and green supply chain processes. Fig. 2 illustrates the model's flow chart. The model subsystems are described as follows.

Raw materials supply

In CHOUKA Iran Wood & Paper Industries Inc., the supply of raw materials for manufacturing paper is one of the major problems, for the most original source of raw materials for paper is the northern industrial forests, which have been on a destructive path. Excessive exploitation of the northern forests is forbidden by the Iranian Department of Environment and Forest Protection; another source and method must inevitably be sought to supply the raw materials in the paper industry.

Wood sources

In general, the raw materials required for producing pulp in the CHOUKA kraft cooking process are supplied from wood and non-wood resource. Wood sources include expoloitation of the northern industrual forests, tree farming, and developing artificial forests with the aim of sustainable development and conservation of resources for future generations, as well as import of wood and pulp. Non-wood resources include using bagasse, sraw, and rice stubble from agricultural waste.

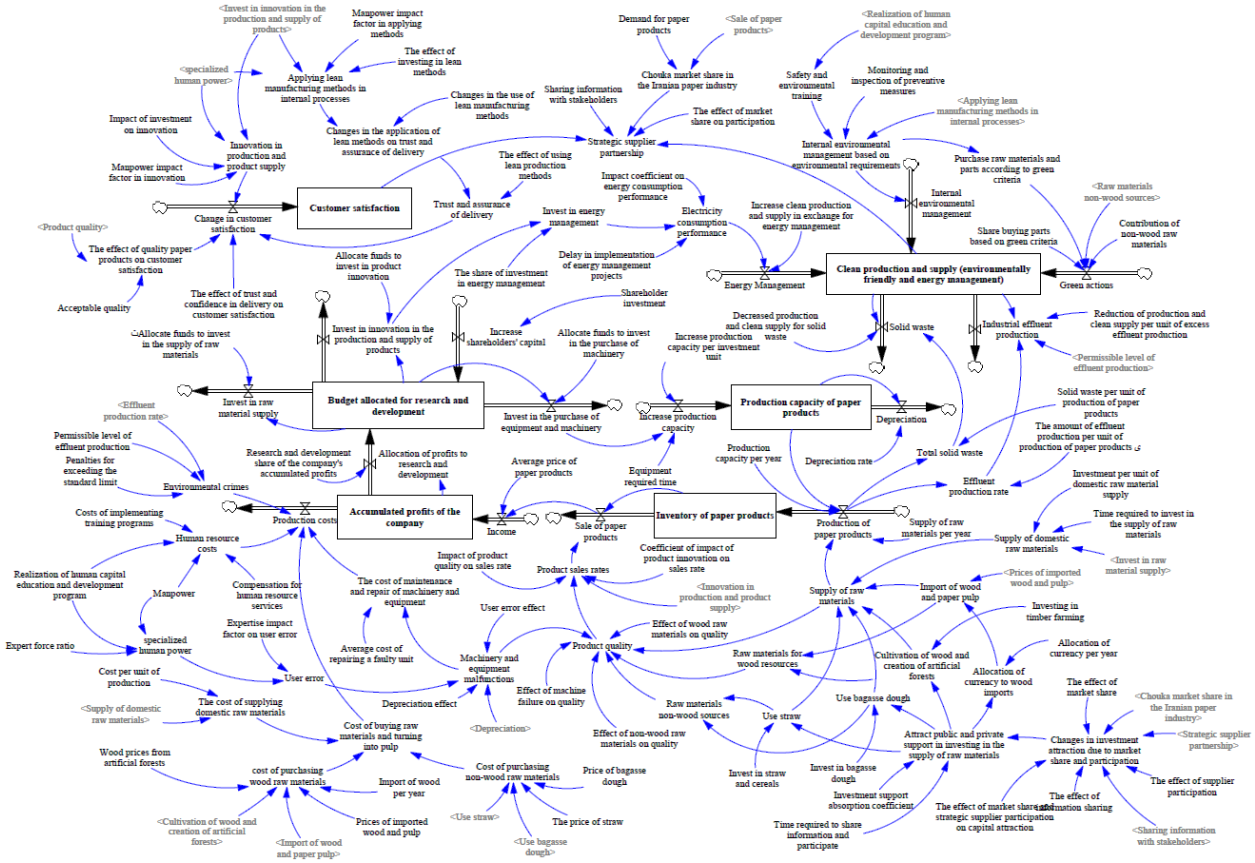

Fig. 2. Iran Wood & Paper Industries supply chain sustainability dynamics model

Financial Resource Flow and Research and Development Investment

The amount of paper production is programmed considering the factory capacity based on the amount of raw materials supply according to the machinery and equipment of the production line. The inventory is changing as for the production timetable and plan and the sales rate of paper products. Sales and growth income of paper products are determined based on the average price and the sales rate. Production costs are examined in four cost flows with respect to the issue. The human resources costs include compensation as well as the costs related to training and human capital development. Machinery and equipment maintenance costs are considered in terms of failure rate and average repair costs, and the costs relevant to purchasing the raw materials and converting them to pulp with respect to the costs involved in purchasing wood and non-wood raw materials and the degree of exploitation. A portion of the corporation's accumulated earnings and profits, calculated in terms of income and production costs, is annually allocated to research and development as budget. In addition, the research and development budget has occasionally been realized by increasing the shareholders' capital .

Factory machinery and equipment

Factory equipment failure and breakdown not only challenges production capacity but also affects the quality of paper products. Machinery exhaustion and excessive maintenance expenses affect factory profitability, as well as the quality and the prime cost of paper products. Expert human resources: Insufficient governmental support for wood and paper industry, a lack of expertise at the management level of this industry, inadequate personnel and worker salaries, and the fact that production in CHOUKA pulp and paper complex has never exceeded 50% of its nominal capacity are all due to several problems and deficiencies, where one of the biggest challenges is a lack of expert human resources and management at different levels. Scarcity of expert and skilled human resources, low-level training facilities, and lack of appropriate

planning for training expert manpower for this industry have led to challenges such as user error during the production process, and such errors are the culprit for some failures and breakdowns in machinery.

Lean supply chain procedure

Strategic collaboration of suppliers helps absorb and invest governmental capital and support for the wood and paper industry. Another component of the lean production procedures subsystem is customer satisfaction. This dimension is assessed based on the constructs of trust and reliability of delivery, innovation in production, and the quality of paper products. The other component is considered information sharing so that the information shared in the supply chain system includes the information between direct partners. It also includes the supply chain network, where information sharing is needed for effective and efficient use by partners. Accordingly, information sharing with stakeholder networks, as well as strategic collaboration with suppliers, plays a considerable role in absorbing capital and receiving governmental support for the wood and paper industry.

Green supply chain procedures

This subsystem includes a series of internal and external actions of the establishment throughout the supply chain, leading to improvements in the environment and prevention from pollution. Applying green supply chain management strategies results in a reduction in waste, in use of resources, and consequently in energy consumption and environmental pollutions. The degree of realizing the goals of green production and supply plans has been considered in terms of energy management plans considered in the electric energy consumption performance model as an effective factor and the green actions due to purchasing raw materials and parts based on green and environmentally-friendly criteria, as well as the amount of non-wood raw materials consumption. Further, safety training, monitoring and inspection of preventive measures, and adopting lean production practices lead to internal environment management based on environmental requirements. Given that the amount of industrial wastewater stems from paper productions, it will be liable to environmental fines in case it exceeds the wastewater production limit, and realization of green production and supply will face challenges. In addition to factory industrial wastewater, the solid waste stemming from paper productions also represents one of the challenges of green supply chain procedures and reduces the chances of realizing green production and supply plans' goals.

Model validation and initial simulation

In addition to expert approval, structural and behavioral validity tests, including model structure and dimension compatibility test, integration error test, extreme condition test, and behavior reproduction test, were performed for the sake of model validation.

After successful results from the model's boundary adequacy, dimensions adaptability, and structural tests in Vensim, the initial simulation of the model could be undertaken. To test the model behavior reproduction, the RMSPE index, which is a statistical method of behavior verification, was calculated. This index measures the root mean squared difference between the actual data (At) and the simulated data (St). To confirm the system behavior, this index should be less than 0.1. Table 1 shows the results of the behavior reproduction test of some model variables according to time series data from 2009 to 2019. 2019 has been considered as the base year according to the most recent available data, and the simulation horizon was presented in 2019-2029 within a 10-year period.

Table 1. Iran Wood & Paper Industries supply chain sustainability system dynamics raw data and constants

Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Unit
Market Share (A_t)	13.05	11.35	10.12	10.33	7.28	7.2	10.4	8.5	9.3	13.05	11.35	Dmnl
Market Share (S_t)	12.5	11.4	10.5	9.84	9.42	9.2	9.1	8.9	8.7	8.3	7.9	RMSPE=0.08
Manpower (A_t)	831	811	779	729	690	684	647	631	634	625	831	Person
Manpower (S_t)	831	811	779	771	751	۷۳۱	711	691	671	651	631	RMSPE=0.08
Inventory Level (A_t)	170	200	206	217	221	253	295	298	325	340	370	Ton×1000
Inventory Level (S_t)	178	258	287	279	287	301	319	313	343	348	349	RMSPE=0.09

As shown in Fig. 3, the stock variable of accumulated earnings and profits follows an ascending trend up to around 8 years into the simulation horizon, and then takes a descending trend afterwards. The stock variable of paper products inventory has an ascending behavior in the simulation horizon. Although the slope is highly sharp until the eighth year, it will be milder afterwards. The model takes on a descending trend in the simulation horizon for the stock variable of paper products production capacity. Fig. 2 illustrates the behavior of this variable and its flow variables. It could be argued that this descending trend is a result of machinery breakdown due to their long life.

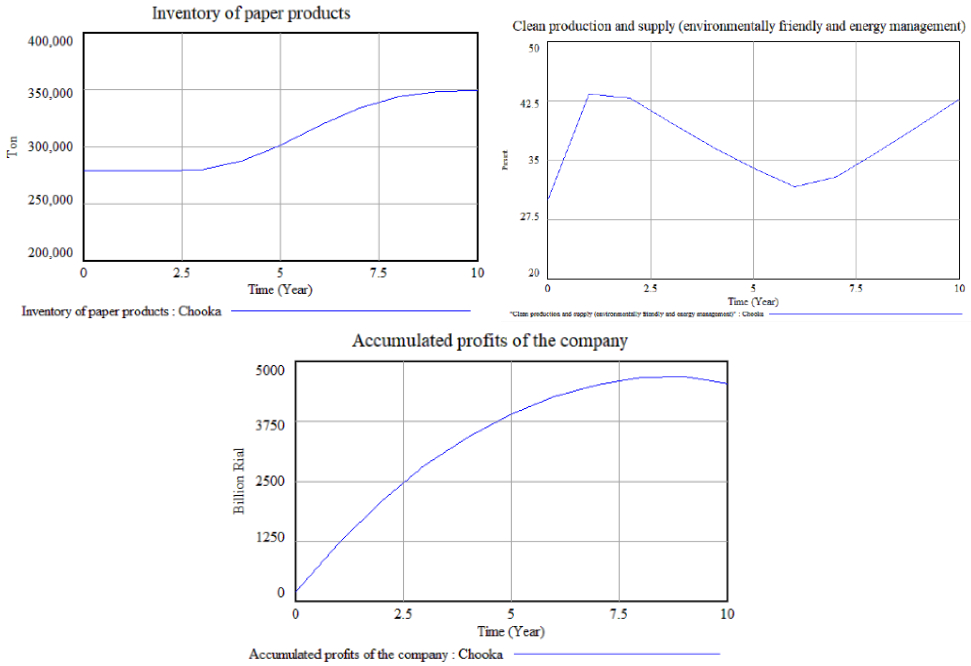

Fig. 3. The behavior of other model variables in the 10-year simulation horizon

System dynamics model's sensitivity analysis

To assess sensitivity analysis in Vensim in flow diagrams, a number of exogenous variables of the flow model are selected, and their effect for two different values in another target variable in the same model is evaluated. Fig. 4 depicts the results of sensitivity analysis along with the relevant charts. According to the results of the model sensitivity analysis, the variables causing the widest range of changes and the so-called leverage points of the model were identified. It is noteworthy that the model has very little or no sensitivity to other exogenous variables

compared to the main target variable, including the company's accumulated profit and earnings, green production and supply, and customer satisfaction.

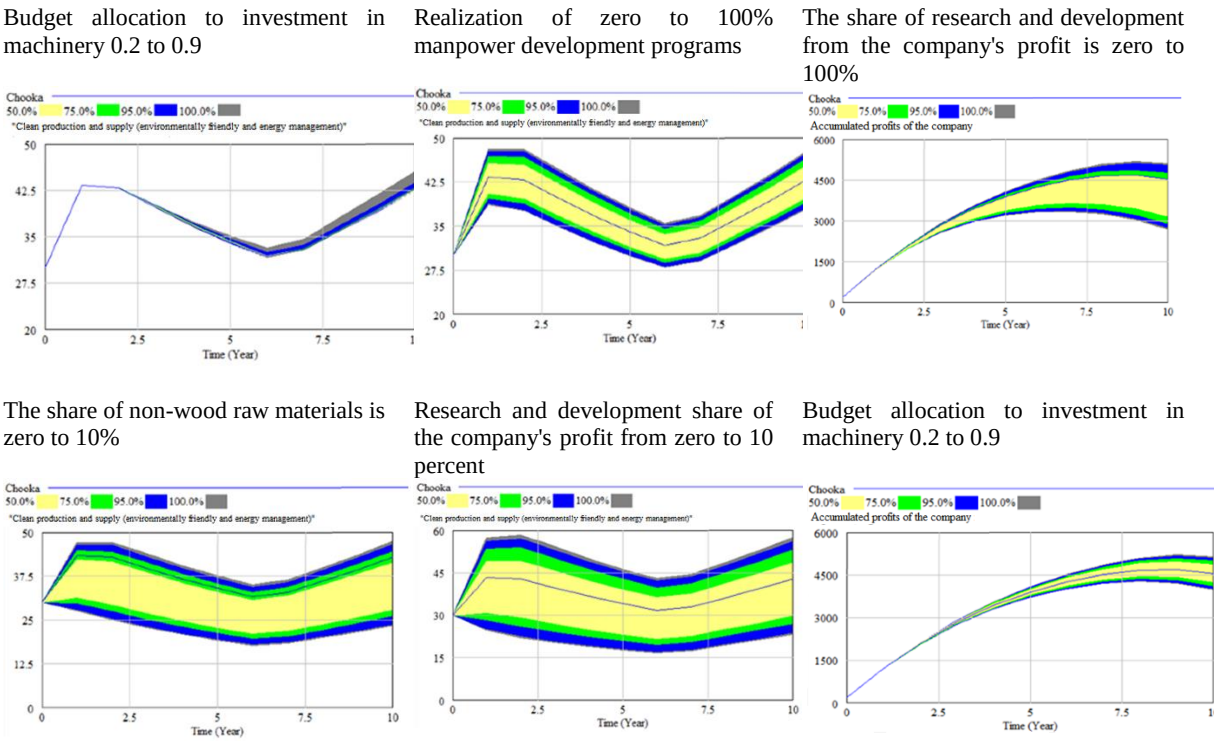

Fig. 4. Exogenous variables and the purpose of sensitivity analysis along with the obtained results in flow charts

Policy-making of the supply chain sustainability of Iran wood and paper industries

After reviewing the results of sensitivity analysis and finding the leverage points of the model and the purpose of modeling in this stage, three categories of solutions were identified with the help of relevant organizational data and the participation of experts. These solution categories included lean supply chain management strategies, green production supply chain management strategies, and business profitability strategies, each of which will be described below.

Lean supply chain management strategy

The category of solutions related to this strategy is designed to focus on the success factors of lean supply chain management. These strategies seek to enhance the strategic collaboration of suppliers, the domestic lean practices, including improving the efficiency of production processes and operations, and the efficiency of quality systems and the application of this method. In addition, communicating with customers in order to increase their satisfaction and increasing information sharing with stakeholders represent the focus of the lean supply chain management strategy.

Green supply chain management strategy

The category of solutions related to green supply chain management strategy is focused on environmental pollution management and responsible consumption. Accordingly, policies for energy consumption optimization, industrial wastewater management, and solid waste management are adopted to manage the green supply chain.

CHOUKA's business profitability strategy

According to the business profitability model in CHOUKA corporation and the business strategies in this company, defined in terms of mission, this category of solutions is focused on the sustainability of CHOUKA'S profitability. Policies were adopted in terms of change in the quality of paper products, innovation in production, technology modernization, raw materials supply management and staff empowerment. An attempt was made to estimate the budget required for implementing each of the policies. Table 2 presents the changes applied to the model and the estimated capital requirements for the annual implementation of policies.

Table 2. Identified strategies and policies and changes applied to the model

Strategies	Policies	Applied changes	Capital estimate
Lean supply chain management strategy	Policy 1: Improving productivity through lean practices in internal processes	Improving materials supply management, improving parts supply by increasing the use of lean practices	5 billion Rials
	Policy 2: Increasing customer satisfaction through innovation and product quality	Increasing the budget allocated to investment in the purchase of machinery, increasing the effect of raw materials quality, and increasing the allocation of research and development budget to innovation in production and supply of products	10 billion Rials
	Policy 3: Increasing strategic collaborations with suppliers	Tripling information sharing with beneficiaries and merging with raw materials supplier companies	-
Green supply chain management strategy	Policy 1: Energy consumption optimization	Increasing the share of investment in energy management	35 billion Rials
	Policy 2: Industrial wastewater management	50% reduction in the rate of industrial wastewater generation per unit of production	14 billion Rials
	Policy 2: Purchasing raw materials and machinery parts based on green criteria	Increasing the budget allocated to purchasing raw materials and machinery parts	5 billion Rials
	Policy 4: Solid waste management	50% reduction in the rate of industrial solid waste generation per unit of production	10 billion Rials
	Policy 5: Preventive monitoring and inspection	Doubling preventive monitoring and inspection	-
CHOUKA's business profitability	Policy 1: Increasing the quality of paper products	Increasing the budget allocated to investment in purchasing machinery and the decreasing effect on the rate of breakdown and the increasing effect of wood and non-wood raw materials quality	175 billion Rials
	Policy 2: Increasing innovation in production and supply of paper products	Increasing the research and development fund allocated to innovation in production and supply of products	8 billion Rials
	Policy 3: Increasing production capacity through technology modernization	Increasing the budget allocated to investment in purchasing machinery	55 billion Rials
	Policy 4: Improving raw materials supply management	Allocating research and development fund to the investment in raw materials supply	5 billion Rials
	Policy 5: Staff empowerment	100% realization of human capital training and development programs	3 billion Rials

- Lean supply chain management strategy

Due to increased investment in adopting lean production practices in CHOUKA's internal processes and productions' quality and innovation enhancement, as shown in Fig. 4, applying this strategy entailed a considerable improvement in CHOUKA's market share. On the other hand, due to the increased information sharing with suppliers, enhanced strategic collaborations with suppliers are witnessed. Change in the strategic collaboration of suppliers on raw materials supply should occur through increased public and private supports. Furthermore, innovation

and quality of raw materials affect the quality of paper products, and this strategy also creates favorable changes in the quality of products. On the other hand, given the increased market share of CHOUKA, as also observed in the paper product inventory variable behavior, a reduction in the paper product inventory will be witnessed. As observed regarding the customer satisfaction variable, the application of this strategy increases the level of customer satisfaction due to the increase in product quality and timely delivery, which are the result of adopting lean practices in internal processes. Nevertheless, this strategy has been unable to significantly improve the company's accumulated earnings and profits compared to the trend followed.

- Green supply chain management strategy

Due to the changes made by the policies of this strategy, as shown in Fig. 4, there is a significant improvement in green production and supply in terms of environmental friendliness and energy management. It is noteworthy that the required capital was applied to the model from the accumulated earnings and profits of the company and the income of shareholders. Given that green production and supply play a great role in improving the strategic collaboration of suppliers, as well as attracting support and investment, this investment also increases the quality of products and market share of CHOUKA. However, the green supply chain management strategy has not changed the production capacity of paper products and the accumulated earnings and profits of the company over the simulation horizon, which indicates that investing in green management and increasing green measures imposes high costs on the system, yet these investments will be economically offset given the increased strategic collaboration of suppliers and the support that is attracted based on this competitive advantage. This strategy has not significantly improved the variables of production capacity and customer satisfaction.

- CHOUKA's sustainable profitability strategy

Due to the changes made by the policies of this strategy, as shown in Fig. 5, there is a significant improvement in the market share of CHOUKA, the production capacity of paper products, the accumulated earnings and profits, customer satisfaction, and product quality over the simulation horizon. In addition, due to the investment in purchasing machinery, the percentage of machinery breakdown also well decreases. Regarding empowerment of specialized human resources, according to the educational planning and development of human resources, expert human resources are trained and empowered to the extent to meet the company needs. Two important points are noted about this strategy. First, the amount of capital required here is much higher than that for other strategies, and not only is this investment made from the company's accumulated earnings and profits but a larger part of it must also be injected by shareholders. The second point is that given that it has not specifically targeted green management, this strategy jeopardizes the green production and supply performance over time, and in this regard, given the impact it has on the strategic collaboration of suppliers, this variable will also undergo a decreasing trend. In the following, comparison charts will be provided to evaluate and compare more strategies.

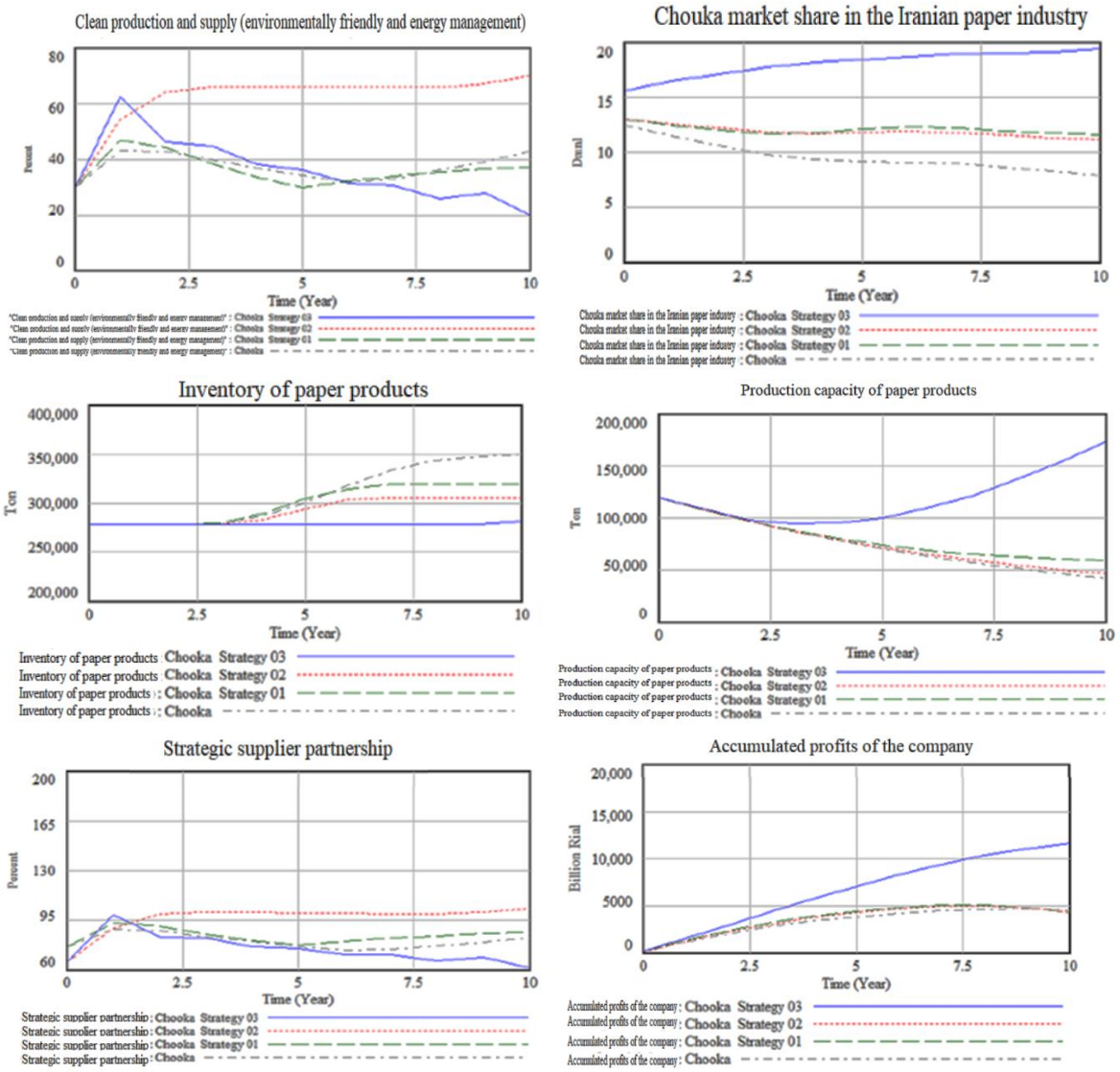

Fig. 5. Behavior of the model's key variables under the sustainable profitability strategy in the 10-year simulation horizon (2019-2029)

Given the results obtained by applying lean supply chain management and green supply chain management strategies as well as CHOUKA's business profitability, as it was observed, each of the strategies focused on certain aspects of competitive advantage, and none of the opportunities alone completely benefited from the opportunities available in this industry. For this purpose, with the participation of experts, all policies were applied to the model taking into account their overlaps, the results were examined, and the policies that were less effective on key variables than other policies were eliminated. Eventually, a combination of three strategies of supply chain management for CHOUKA based on competitive advantage was selected, including improving productivity through lean practices in internal processes with an estimated budget of 5 billion Rials, increasing the quality of paper products with 175 billion Rials, increasing innovation in production and supply of paper products with 8 billion Rials, managing industrial wastewater with 14 billion Rials, managing solid waste with 10 billion Rials, improving raw materials supply management and strategic collaboration with raw materials suppliers with 5 billion Rials, and empowering staff with 3 billion Rials annually. Table 3 shows the combination of policies and changes applied to the model. The behavior of key variables under the selected CHOUKA supply chain management strategies applied based on competitive advantage is presented in Fig. 6.

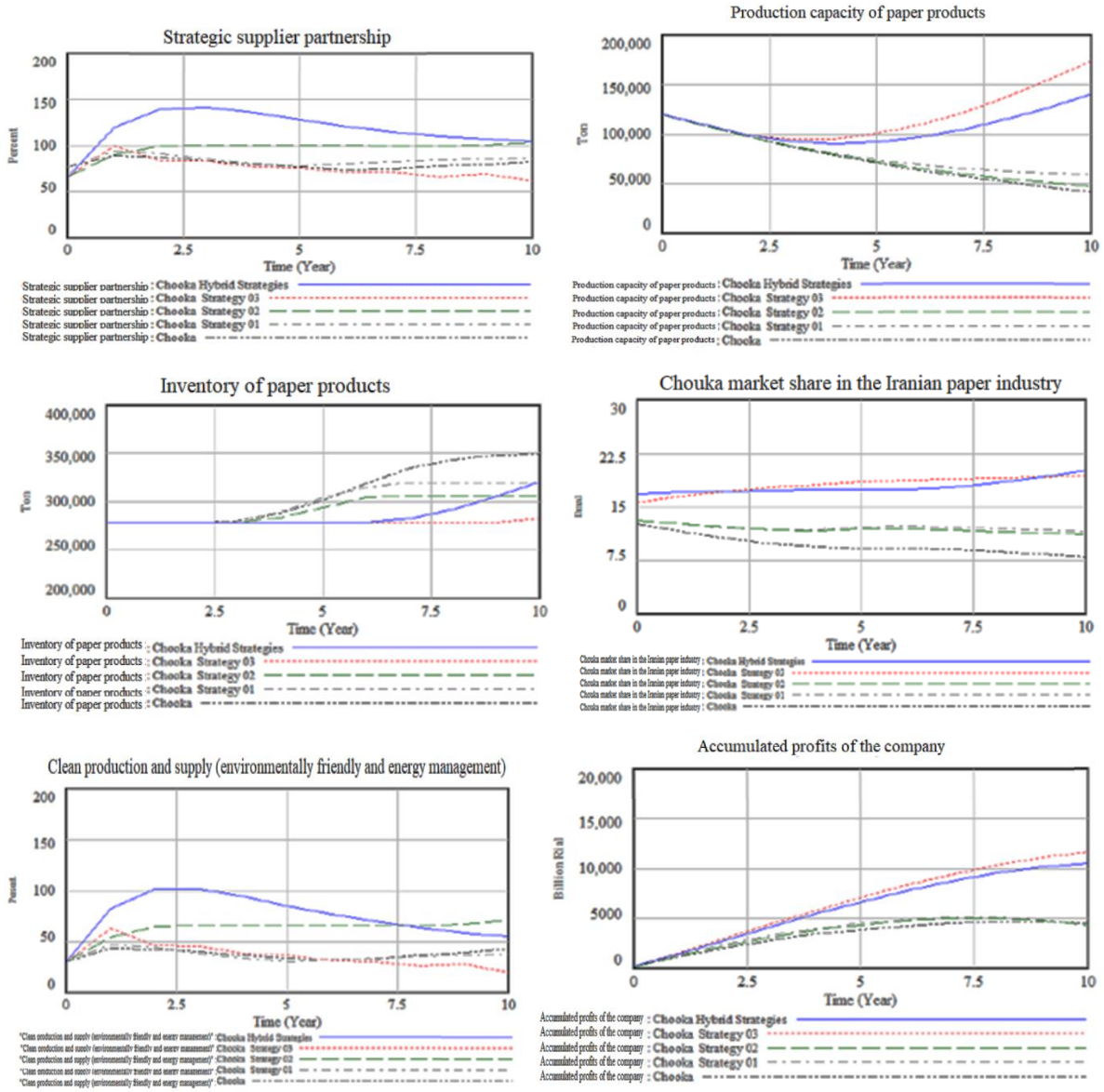

Fig. 6. Behavior of the model's key variables under the combined strategy in the 10-year simulation horizon (2019-2029)

As for the results of the behavior of key variables in the simulation horizon, as seen in Fig. 5, by applying a combined strategy in terms of profitability compared to the sustainable profitability strategy, the company's accumulated earnings and profits are slightly reduced as a result of investments in research and development on green management and the application of lean production practices in the processes, and these investments will of course return to the system owing to collaboration, support and investment in the supply of raw materials. In the combined strategy, customer satisfaction and green production and supply account for the highest improvement compared to separate strategies. Although the market share is almost in line with the sustainable profitability strategy until about the ninth year into the simulation, it is on the rise thereafter. According to the above results and the comparison between different solutions, the selected combination strategy, which is derived from lean and green supply chain management policies, as well as CHOUKA's business profitability business strategy, is presented as the supply chain management sustainability of Iran wood and paper industries.

Conclusions and recommendations

Sustainability of the supply chain in economic systems and green supply chain management by raising awareness of environmental effects have widely attracted researchers' attention. On the other hand, the lean supply chain is another concept whose implementation in organizations is expected to result in improved sustainability in industries. This study aimed to analyze the policy-based roles of lean and green supply chain concepts in the corporation sustainability by designing a system dynamics model of the supply chain in CHOUKA Iran Wood & Paper Industries Inc. To this end, after a review of the literature with collaborations from decision-makers and CHOUKA data, the system was designed, and the model was simulated in a 10-year horizon after validation. Considering the behavior of the variables and the Monte Carlo sensitivity analysis in the simulation horizon, the green supply chain policies, the lean supply chain management and CHOUKA's business profitability were designed and applied to the model both in separate and integrative manners, the results were compared, and the behaviors of the policies were analyzed. As for the findings of the model simulation, the selected combination of the policies of lean supply chain management and green supply chain management, as well as CHOUKA's business profitability, was proposed as the best integrative sustainability policy for CHOUKA Iran Wood & Paper Industries supply chain management. In general, the results showed that the simultaneous implementation of lean and green supply chain policies will lead to synergy in supply chain sustainability; accordingly, the findings of the present study are in line with those of Tafreshi Motlagh et al. (2017), Yang et al. (2011), Davis et al. (2012), Rosen (2013) Pampanelli, Fando Bernardes (2013), Johnson and Sundin (2014) and Bissarizo and Karimiads (2014). In addition, an attempt was made in this study to provide a modeling and simulation approach in order to formulate supply chain strategies and to provide grounds for the development of supply chain models and supply chain strategies. The researcher faced limitations in the research process. Due to the lack of accurate information available to predict the demand for paper and paper products, future prices of paper and paper products, estimated values were used; it is recommended for future research to develop a model with respect to these variables to obtain more accurate estimates.

References

[1] Xu, J., Cao, J., Wang, Y., Shi, X., & Zeng, J. (2020). Evolutionary game on government regulation and green supply chain decision-making. Energies, 13(3), 620.

[2] Reche, A. Y. U., Junior, O. C., Estorilio, C. C. A., & Rudek, M. (2020). Integrated product development process and green supply chain management: Contributions, limitations and applications. Journal of Cleaner Production, 249, 119429.

[3] Jemai, J., Do Chung, B., & Sarkar, B. (2020). Environmental effect for a complex green supply-chain management to control waste: A sustainable approach. Journal of Cleaner Production, 277, 122919.

[4] Wang, C., Zhang, Q., & Zhang, W. (2020). Corporate social responsibility, Green supply chain management and firm performance: The moderating role of big-data analytics capability. Research in Transportation Business & Management, 37, 100557.

[5] Tafreshi Motlagh, A., Olfat, L., Bamdad Soufi, J., Amiri, M. (2016). Presenting an Integrated Model to Explain the Effects of Both Lean and Green Supply Chain on Corporate Sustainability. Iranian journal of management sciences, 11(44), 1-24.

[6] Diabat, A., & Govindan, K. (2011), An analysis of the drivers affecting the implementation of green supply chain management, Resources, Conservation and Recycling,55(6), 659–667.

[7] Johansson, G., & Sundin, E. (2014), Lean and green product development: Two sides of the same coin?, Journal of Cleaner Production, 85(85), 104–121.

[8] Besseris, G. J., & Kremmydas, A. T. (2014), Concurrent multi-response optimization of austenitic stainless steel surface roughness driven by embedded lean and green indicators, Journal of Cleaner Production,85, 293–305.
[9] Rebs, T., Brandenburg, M., & Seuring, S. (2019). System dynamics modeling for sustainable supply chain management: A literature review and systems thinking approach. Journal of Cleaner Production, 208, 1265–1280.
[10] Raut, R. D., Narkhede, B., & Gardas, B. B. (2017). To identify the critical success factors of sustainable supply chain management practices in the context of oil and gas industries: ISM approach. Renewable and Sustainable Energy Reviews, 68, 33–47.
[11] Malviya, R. K., & Kant, R. (2016), Hybrid decision making approach to predict and measure the success possibility of green supply chain management implementation, Journal of Cleaner Production,135, 387–409.
[12] Fercoq, A., Lamouri, S., & Carbone, V. (2016), Lean / Green integration focused on waste reduction techniques, Journal of Cleaner Production,137, 567–578.
[13] Li Suhong, S. Subba Rao , T.S. Ragu-Nathan , Bhanu Ragu-Nathan, (2005),Development and validation of a measurement instrument for studying supply chain management practices, Journal of Operations Management 23 ,pp 618–641.
[14] Cees J. Gelderman,Janjaap Semeijn,Mark Verhappen,(2020)Buyer opportunism in strategic supplier relationships: Triggers, manifestations and consequences,Journal of Purchasing and Supply Management, Journal of Purchasing and Supply Management,Volume 26, Issue 2, March 2020, 1-32.
[15] Chavez, Wantao Yu, Mark A. Jacobs, Mengying Feng,(2017), Manufacturing capability and organizational performance: The role of Entrepreneurial orientation, International Journal of Production Economics 184 ,33–46
[16] Moharramzadeh, M., Pashaie, S., Hoseyni, M. (2019). The Effect of Customer Relationship Management on Satisfaction and Loyalty of Customers Referring to Sports Places. *Communication Management in Sport Media*, 6(4), 67-76. doi: 10.30473/jsm.2019.46242.1324.
[17] Song, M., Cui, X., Wang, Sh., 2019, Simulation of land green supply chain based on system dynamics and policy optimization, International Journal of Production Economics, Vol. 217, pp. 317-327,
[18] Zhao, P., Yin, S., Han, X., & Li, Z. (2021). Research on lean supply chain network model based on node removal. Physica A: Statistical Mechanics and its Applications, 567, 125556.
[19] Wang, C., Zhang, Q., & Zhang, W. (2020). Corporate social responsibility, Green supply chain management and firm performance: The moderating role of big-data analytics capability. Research in Transportation Business & Management, 37, 100557.
[20] Yousefi-Babadi, A., Bozorgi-Amiri, A. and Tavakkoli-Moghaddam, R. (2021), "Sustainable facility relocation in agriculture systems using the GIS and best–worst method", Kybernetes, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/K-03-2021-0189
[21] Tafakkori, K., Bozorgi-Amiri, A., & Yousefi-Babadi, A. (2020). Sustainable generalized refueling station location problem under uncertainty. Sustainable Cities and Society, 63, 102497.
[22] Bappy, Mahathir Mohammad; Ali, Syed Mithun; Kabir, Golam; Kumar Paul, Sanjoy;. (2019). Supply chain sustainability assessment with dempster-shafer evidence theory: Implications in cleaner production. Cleaner Production. Vol, 237.
[23] Khorasani, S. T., Cross, J., & Maghazei, O. (2020). Lean supply chain management in healthcare: a systematic review and meta-study. International Journal of Lean Six Sigma.
[24] Zhou, H., & Li, L. (2020). The impact of supply chain practices and quality management on firm performance: Evidence from China's small and medium manufacturing enterprises. International Journal of Production Economics, 230, 107816.
[25] Izadyar, M., Toloie-Eshlaghy, A., & Seyed Hosseini, S. M. (2020). A Model of Sustainability Performance Assessment of LARG Supply Chain Management Practices in Automotive Supply Chain Using System Dynamics. Industrial Management Journal, 12(1), 111-142.
[26] Gupta, V., Narayanamurthy, G., & Acharya, P. (2018). Can lean lead to green? Assessment of radial tyre manufacturing processes using system dynamics modelling. Computers & Operations Research, 89, 284-306.

[27] Bahmani, A., and Rafiqi, A., and Wali, M., and Salari, A. (2011). Identifying and evaluating the challenges facing the country's wood and paper industries. Iran Wood and Paper Industries, 2 (2), 27-38. https://www.sid.ir/fa/journal/ViewPaper.aspx?id=172638.

[28] Ramzanian M R, rahmany Z, hoseinijou S A, mobasher amini R A. Dealing with Supply Chain Complexity using Theory of Constraints Thinking Processes (Case Study of a Paper Manufacturing Firm). IQBQ. 2013; 17 (2):125-144

[29] Zadmirzaiee Soleiman darabi & Limaiee (2016). Applying the data envelopment analysis fundamental models for determining of relative efficiency of Mazandaran Wood and Paper Industry Company. Journal of Wood and Forest Science and Technology, 23(2), 1-20. doi: 10.22069/jwfst.2016.3096. (In Persian).

[30] Sterman. (2000). Business Dynamics: Systems Thinking and Modeling for a complex word. Boston: Permission of the McGraw-Hill companies.