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RESEARCH ARTICLE **Open Access**

Four-stage Supply Chain Design for Perishable Products and evaluate it by Considering the Triple Dimensions of Sustainability

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Abstract
This study will seek to provide the best and most efficient ordering policies for different levels of the perishable food supply chain in order to maximize the overall profit of the chain, and minimize social and environmental damage. Our supply chain includes a four-level supply chain of suppliers, manufacturers, distributors and retailers. In addition to the components of perishable products, the dimensions of sustainable development have been fully investigated and taken into account in the entire chain. In this study, due to the main nature of perishable materials, the statistical population includes 9 dairy companies and 9 meat and protein companies, which in total 18 dairy, meat and protein companies in Fars province, Iran, were studied. Network Data Envelopment Analysis (DEA) was used to analyze the data and WinQsb was used to model and solve it. According to the results, the average efficiency of the supply chain of production and distribution of perishable products in the financial year studied by the research in the suppliers sector was equal to 0.9634. This average was equal to 0.9899 in the producers sector, 0.9903 in the distributors sector and 0.9707 in the retailers sector. Therefore, the average efficiency in the study shows that the most inefficiency problems of the studied companies are related to the supplier sector. Also, the overall average efficiency is equal to 0.9950.
Keywords: Sustainable Supply Chain, Sustainable Supply Chain Performance Evaluation, Perishable Products, Food Industry

Introduction

Food spoilage is a common phenomenon in everyday life. Products such as vegetables, fruits, dairy products, meat, medicine, etc. have a fixed and short life. These types of products are known as perishable goods. These goods can be stored in the warehouse for a short period of time, because their value will decrease with the increase of storage time in the warehouse, therefore, the activities that lead to an increase in the demand for these products and as a result reduce their storage time are of great importance. Perishable products can be optimized economically, socially and environmentally by designing a sustainable supply chain for perishable products in companies (Paidar, Abass et al., 2021). Current consumption and production patterns are considered as a threat to the environment and food security of future generations (Shourangiz, Abdulaziz et al.,

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2021). Therefore, the time of decision about the food system has become very important with the occurrence of more environmental problems and more awareness of society (S. U. K. Rohmer,, J. C. Gerdessen , G. D. H. Claassen., 2019). Also, the need for appropriate reactions of organizations has doubled with the intensification of the global competition scene in an environment that is constantly changing, and it has been emphasized on their flexibility with the uncertain external environment. In the meantime, the food supply chain is one of the most complex and largest sectors of the world's industry, and ensuring the safety and quality of food has always been a priority (Michael Bourlakis et al., 2014). Sustainability plays a key role in successful and responsible business management. There are three major challenges when trying to improve business sustainability performance. First, sustainability assessment needs to consider not only economic factors but also social and environmental impacts (Rahchamani, Seyed Mohammad et al., 2022). Then, we seek to find appropriate sustainability indicators and collect the necessary information to evaluate sustainability performance. Finally, sustainability should be considered in the framework of the whole system, that is, it should include all activities of the supply chain (Zhang, Q., Shah, N., Wassick, J., Helling, R., Egerschot, and P.V.., 2014).

Although valuable efforts have been made to construct and assess sustainability in the food and agriculture sector for easy and correct management, no internationally accepted criteria unambiguously define what food production includes. Also, there is no accepted definition of the minimum requirements that qualify a company as a sustainable company. Sustainable supply chain management has received the attention of many researchers and experts in the past years (Mehdi, R., & Shafiee, M, 2017). It is considered as a method to simultaneously improve economic, social and environmental performance. Therefore, evaluating sustainable supply chain management is an important task for any type of organization (Khoda Karmi et al., 2015). Supply chain sustainability has become one of the most dynamic areas of decision-making management over the past 30 years (Shafiee, M., & Ahmadi, M, 2012). According to the results of a systematic review of 198 studies published between 1995 and 2018, it can be concluded that the entire sustainable aspects of the supply chain are still not fully addressed (C.L. Martins, M.V. Pato, 2019). The growth of social and environmental concerns about the effects of the food supply chain on the natural environment has led to increasing pressure from various stakeholders to improve the sustainable performance of the product life cycle from "farm to people" (Lotfi et al, 2012). The food industry is considered as one of the first industries that have paid attention to sustainability aspects, including pollution, work standards, ethics in supplier relations, and waste-related issues (Yakovleva, N., Sarkis, J., & Sloan, T.., 2011). However, many challenges remain in this field and in this industry, challenges such as very little attention to the social dimension in terms of sustainability, which leads to irreparable social damage, and challenges such as environmental risks, which is always considered as today's debates all over the world (Rohmer et al., 2019). In terms of the economic aspect, costs continue to play a key factor in the decision-making process, because profit margins for food products are often low, competition is high, and food prices are generally a key issue in today's society (Shafiee, M., & Saleh, H, 2019). Therefore, it is necessary to act on the sustainable design of the food system considering costs, food and environment together in order to make sustainable decisions (Rohmer et al., 2019). There are many inventory systems in the food industry, which have items with a limited life or so-called perishables (Jassbi, Abdollah et al., 2021).

Perishable items include a wide range of products including food, fruit, blood, flowers, medicine and clothing (Heidari, Shahab et al., 2021). Paying attention to the modeling of perishable products in the form of a supply chain is very important due to the high use of these products (Shafiee et al., 2014). On the other hand, it is important to review the contracts and rules between the members of a supply chain for people to make decisions in interactive conditions as well. This study will seek to provide the best and most efficient ordering policies for different levels of the perishable food supply chain in order to maximize the overall profit of the chain, and minimize social and environmental damage. Our supply chain includes a four-level supply chain of suppliers, manufacturers, distributors and retailers. The dimensions of sustainable development have been fully investigated and finally, the overall performance of the chain is obtained.

-The main research question:

- How to design and evaluate the supply chain performance of perishable products with a sustainable development approach?

- Research sub-questions:

- What is the structure of the supply chain of perishable products according to sustainable development criteria?
- What indicators are there in the proposed structure of the supply chain of perishable products?
- What are input and output indicators of the supply chain network structure?
- What is the appropriate model for evaluating the performance and analyzing the efficiency of the proposed supply chain?
- How to determine the efficiency of the designed supply chain?
- How is the ranking of efficient units?
- Is there a possibility of sensitivity analysis for chain planning?

Research Background

In recent years, the scientific society pays more attention to articles and research related to supply chain and sustainability in the field of perishable products, which indicates the new trend in the field of supply chain management, environmental management, design and planning. Related articles will be reviewed in general. S. U. K. Rohmer,, J. C. Gerdessen , G. D. H. Claassen. (2019), has conducted a study called "Sustainable supply chain design in the food system by considering food considerations: a multi-objective analysis", the findings of this study are multi-purpose, which highlights the importance of consumption and production decisions in an integrated and global environment. Furthermore, the selection of sustainability index plays an important role due to the contradictory nature of different aspects of sustainability.

C.L. Martins, M.V. Pato,, (2019), in an article entitled "Sustainability of the supply chain: literature review", have reviewed the concepts of supply chain management, sustainability perspectives and methodological literature review characteristics from a systematic review of 198 studies published between 1995 and 2018. The findings of this study create a triple perspective in the field of sustainability. The secondary study of this study provides a comprehensive critical review of the current state of research in the field of supply chain sustainability. Xueli Ma, Shuyun Wang, Qingguo Bai,., (2019) during a study entitled "Coordination of Production Planning and Routing Issues for Perishable Food Products", examines the integrated optimization of production planning issues for perishable food products. According to the results, adjusting the production order and vehicle route simultaneously can improve the quality of perishable food products and the level of customer service significantly. The proposed hybrid algorithm can obtain optimal stable solutions in a limited time period for different sizes.

Yavari Mohammad, Mohaddese Geraeli, (2019), during a study entitled "Exploratory method for sustainable optimization model for green supply chain design of perishable products", has investigated a green design of green package supply chain for perishable products under adverse conditions. According to the results, the strong model has a high quality compared to the deterministic model and seems to be very reliable. Also, according to the results, there is a significant difference between the effects of product life span and uncertainty in environmental costs and objectives of environmental pollution.

Saavedra M et al, (2018), in an article entitled "Sustainable and Renewable Energy Supply Chain: A System Dynamics Theory", extensively reviewed renewable energy and sustainable supply chain management in the past decade. According to the results, the simulations can help to evaluate different options regarding in environmental, economic and social conditions, as well as the introduction of new sources of second and third biofuels.

Jadhav et al, (2018), during a study entitled "The role of supply chain orientation in achieving a sustainable supply chain", concluded that supply chain orientation has the potential to contribute to sustainable supply chain performance. According to the findings, different supply chain orientation structures have different effect approaches in relation to sustainable supply chain performance.

Das Kanchan, (2018), during a study entitled "Integrating lean systems in designing a sustainable supply chain model", concluded that lean-based systems include several methods and tools that can train the organization in terms of economic, environmental and social sustainability. This study helps supply chain managers in choosing green practices in addition to cluster technology based on the unique situations of their business to achieve sustainable triple goals.

Mani Venkatesh a, Gunasekaran Angappa, (2018), during an article entitled " "Four forces of supply chain social sustainability adoption in emerging economies ", concluded that despite the stakeholders' awareness of the issues and benefits related to social sustainability, little attention has been paid to the social dimension of the sustainable supply chain. The results are consistent with the hypothesis model and show all the influencing factors and positive links with the benefits of the companies. This study has identified various forces in the acceptance of social sustainability and its results. Mores et al, (2018), in an article entitled " Sustainability and innovation in the Brazilian supply chain of green plastic", concluded that climate changes has intensified the demand for better efforts to protect the environment the motivation of organizations to make more use of the development of sustainable technologies. According to the results, it is important and necessary to cooperate between the central organization and other factors of the supply chain for product development. Gómez Luciano et al (2018), in an article entitled "Sustainable Supply Chain Management: Participation in the Commodity Market", concluded that the concerns of sustainable development factors in the food supply chain are increasing. This study argues Glocal (The combination of the Global and Local Sourcing and Supply Chain (GSSC)) in developing countries to implement sustainable supply chain. This study analyzes the supply chain to address this gap, and its performance is determined with respect to sustainable indicators considering the importance for developing countries that propose the Glocal model. Raj et al, (2018), during an article entitled " Designing supply contracts for the sustainable supply chain using game theory", investigated the issues related to sustainable supply chain coordination that arise due to the simultaneous attention to environmental and corporate social responsibility (CSR) projects in the supply chain. According to the results, the two-way policy fully coordinates the supply chain, and the channel coordination mechanisms between the supplier and the buyer improve the greenness and the level of corporate social responsibility. Siddhartha et al, (2018), during a study entitled "A framework for selecting supply chain processes and industries using a unified approach", introduced a process view of sustainable supply chain management and identifies 17 sustainable supply chain processes (SSCPs) from literature. The results of this research provide an approach to increase supply chain sustainability that can be extended across industries through a supply chain process perspective in emerging economies such as India. Roy et al, (2018), has carried out a study entitled "thematic perspective of the literature in sustainable supply chain management (examination of the main factors in the development of sustainable supply chain management): with the aim of a comprehensive review of the literature on sustainable supply chain management, with the specific aim of thematic exploration of literature in order to express the main aspects of the development of sustainable supply chain management. The results of the literature review are to provide assumptions for the transition from traditional supply chain to sustainable supply chain. A thematic perspective for sustainable supply chain management literature is proposed, focusing on the main points of development of sustainable supply chain management using the aforementioned comprehensive review. Jiang and Tapan, (2018), has carried out a study entitled "Sustainable coffee supply chain management: case study: A city in Vietnam", with the aim of analyzing and discussing the evolution related to sustainable coffee supply chain and its management in Vietnam. Research analysis confirms that although productivity is high and farmers have a positive experience in this sector, sustainability issues are still emerging. Bastas Ali , Liyanage Kapila, (2018), during a study entitled "Sustainable Supply chain quality management (SCQM): A Systematic Review", concludes that maintaining the level of profitability while doing business through sustainable environmental and social activities is an optimization challenge for organizations globally and for Society. According to the results, a new field of research was identified as the Emerging Supply chain quality management. Jia et al, (2018), has done an article etitled "Sustainable Supply Chain Management in Developing Countries: Literature Analysis", with the aim of providing an analysis of academic literature on sustainable supply chain management practices in developing countries. This study concludes by identifying a gap in the literature that requires more research on this topic, especially in developing countries. Dafne et al, (2018), in an article entitled "Advancement of social sustainability in supply chain management": examined lessons from several studies in emerging economies, by reviewing supply chain management literature, and found that social dimensions have not been investigated. According to the results, social sustainability is intrinsic motivation. Social initiatives are extrinsic motivations that were only associated with more information exchange. Finally, this study helps management with real actions to have more sustainable results by strengthening social sustainability relationships and reasoning to supply chain management. Wang and Dai, (2017), has done an article entitled "Sustainable Supply Chain Management Performance and Practices", with the aim of significantly contributing to empirical research on the impact of sustainable supply chain management on the performance of Chinese companies. According to the results, internal sustainable supply chain management measures have a positive effect on the company. Furthermore, there is a positive relationship between environmental performance and social performance with economic performance. Mathivathanana Deepak et al (2017), in an article entitled " Sustainable supply chain management practices in Indian automotive industry: A multi-stakeholder view", introduces the automotive industry as one of the largest manufacturing sectors, which has a profound impact on society and the environment. According to the results, management's commitment to sustainability and the implementation of the triple approach in strategic decision-making are the most effective methods for implementing sustainable supply chain management. This study provides a platform for industry managers to improve their understanding of the interplay between practices and increase the likelihood of successful implementation of sustainable supply chain management in the automotive industry. Wladimir E. et al., (2017), in an article entitled "Optimization of fresh food logistics for processing: application to a large Chilean apple supply chain", this research presents optimization models that deal with three types of decisions related to horticulture, purchasing, transportation and storage of products. The results show that, in the separate purchase model, products that have a high quality level and can be stored for a longer period of time.

According to the research results and literature findings, the least attention has been paid to the social dimension of supply chain sustainability, and the most attention has been paid to the environmental and economic aspects. Also, little attention has been paid to perishable products in the food industry. Most of the studied sustainable supply chains are one- or two-level sustainable supply chains. This study will try to solve some of these problems by considering several products in the supply chain, the limitations of countries, paying more attention to social aspects in sustainable development, using real food industry data and scenarios, examining the supply chain in a four-level environment and considering the dimensions of sustainability and perishable products-related indicators.

Research Methodology

In this section, the network data overlay analysis model was used in order to evaluate the performance of the research supply chain and calculate the efficiency of the research units with the approach of paying attention to perishable products. Because, conventional data envelopment analysis models ignore the steps and internal processes inside DMUs. In fact, conventional DEA models consider each company as a DMU, and limit their calculations to initial inputs and final outputs. Therefore, due to the use of DEA in the buyer-seller, production-distribution and performance evaluation of supply chains in recent years, and given that the supply chain is considered as a type of decision-making unit that does not only have input and output indicators, but also uses intermediary indicators that flow from the previous stage to the next stage, and each stage may have its own inputs and outputs, hence, traditional data coverage analysis models are not able to correctly and completely evaluate the performance of the supply chain due to the network or multi-stage nature of the supply chain. And for this reason, this study has used the NDEA model with a new approach and it has been calculated according to the sustainability indicators of perishable products and the efficiency of 18 manufacturing supply chains of dairy, meat and protein products.

Identifying indicators for Sustainable Supply Chain Performance Measurement network of perishable products

Studying and knowing the effective parameters in the field of research is a requirement of any applied research. For this purpose, extensive field and library studies were conducted on variables and indicators in the field of various supply chain activities in order to identify and extract effective input and output and intermediate indicators in order to calculate the reliability and evaluate the relative performance of the supply chain in the suppliers sector, and after examining and studying the articles, of specific effective indicators was prepared as described in table (1) in order to fully understand all the research indicators:

Table 1.
Indicators for Sustainable Supply Chain Performance Measurement of perishable products based on previous studies

Indicators for Sustainable Supply Chain					
Environmental	**Researchers**	**Social**	**Researchers**	**Economic**	**Researchers**
Number of green products (green production)	Mirhedayatian and et al (2014) Gómez-Luciano Cristino Alberto et al (2018)	Work safety, health and workforce health	Mirhedayatian and et al (2014) Paciarotti and Torregiani (2021) Biuki and et al (2021) Santos (2019) Gómez-Luciano Cristino Alberto et al (2018) Yousefi et al (2016)	The cost of marketing and advertising campaigns	Taghikhai and et al (2021) Martins and Pato (2018)
Seasonal process of crop corruption	Janssen Larissa et al (2016)	Supplier's fee	Mirhedayatian and et al (2014)	The cost of sustainable environmental choices at all stages of food production	Paciarotti and Torregiani (2021)
Returned product percentage	Yavari Mohammad, Mohaddese Geraeli (2019) TejaMalladi Krishna, Sowlati Taraneh, (2018)	Workers' rights	Paciarotti and Torregiani (2021) Biuki and et al (2021)	The cost of innovative distribution systems	Paciarotti and Torregiani (2021)
Percentage of food waste	Krishnan Ramesh et al (2020) Kamble Sachin.S et al (2019) Gómez-Luciano Cristino Alberto et al (2018) Giang N. T. Nguyen, Tapan Sarker (2018) Janssen Larissa et al (2016)	The number of workers	Biuki and et al (2021) Kamble Sachin.S et al (2019) Moreno-Camacho Carlos et al (2019)	Diversity of services	Mirhedayatian and et al (2014)
rate of dependence of freshness	Sebatjane Makoena, Adetunji Olufemi (2020) Giang N. T. Nguyen, Tapan Sarker (2018)	The amount of satisfaction of workers and employees	Biuki and et al (2021) Santos (2019) Yousefi et al (2016)	Production quality	Paciarotti and Torregiani (2021) Moreno-Camacho Carlos et al (2019) Yousefi et al (2016)

Indicators for Sustainable Supply Chain					
Environmental	**Researchers**	**Social**	**Researchers**	**Economic**	**Researchers**
	Kaasgari et al (2016)				
Number of mortal items (all kinds of corrupt food products)	Sebatjane Makoena, Adetunji Olufemi (2020) Xueli (2019) Kaasgari et al (2016)	Customer satisfaction	Gómez-Luciano Cristino Alberto et al (2018) TejaMalladi Krishna, Sowlati Taraneh, (2018)	The cost of ordering	Kaasgari et al (2016) M.A.H. van Elzakkera et al (2014)
Reduce CO_2 gas	Mirhedayatian and et al (2014) Jia Fu et al (2020) Santos (2019) Das Kanchan (2018) Gómez-Luciano Cristino Alberto et al (2018) TejaMalladi Krishna, Sowlati Taraneh, (2018)	Stakeholder satisfaction	Yousefi et al (2016)	Maintenance costs	Kaasgari et al (2016) M.A.H. van Elzakkera et al (2014)
The cost of supplying organic raw food	Mirhedayatian and et al (2014) Santos (2019) M.A.H. van Elzakkera et al (2014)	The amount of attention to the local market	Kamble Sachin.S et al (2019) Gómez-Luciano Cristino Alberto et al (2018) Giang N. T. Nguyen, Tapan Sarker (2018)	The cost of transportation of resources	Salehi Amiri and et al (2020) Sebatjane Makoena, Adetunji Olufemi (2020) Jouzdani Javid, Govindan Kannan (2020) Arkajyoti De, Surya PrakashSingh (2020) Sinha Amit Kumar, Anand Ankush (2020) Rohmer et al (2019) Martins and Pato (2019) Xueli (2019) Das Kanchan (2018) TejaMalladi Krishna, Sowlati Taraneh, (2018) Wladimir et al (2017) Ramezanian Reza, Behboodi Zahra (2017) Janssen Larissa et al (2016) M.A.H. van Elzakkera et al (2014)
Pest and artificial fertilizers	Taghikhai and et al (2021) TejaMalladi Krishna, Sowlati Taraneh, (2018)	Average credit factor	Mirhedayatian and et al (2014)	Transportation of final goods	Salehi Amiri and et al (2020) Sebatjane Makoena, Adetunji Olufemi (2020)

Indicators for Sustainable Supply Chain					
Environmental	**Researchers**	**Social**	**Researchers**	**Economic**	**Researchers**
					Jouzdani Javid, Govindan Kannan (2020) Arkajyoti De, Surya PrakashSingh (2020) Sinha Amit Kumar, Anand Ankush (2020) Rohmer et al (2019) Martins and Pato (2019) Xueli (2019) Das Kanchan (2018) Wladimir et al (2017) Janssen Larissa et al (2016) M.A.H. van Elzakkera et al (2014)
Attention to the water	Paciarotti and Torregiani (2021) Kamble Sachin.S et al (2019) Moreno-Camacho Carlos et al (2019) Saavedra et al (2018) Jadhav et al (2018) Gómez-Luciano Cristino Alberto et al (2018) Giang N. T. Nguyen, Tapan Sarker (2018) Yousefi et al (2016)	Proper pension	Paciarotti and Torregiani (2021) Biuki and et al (2021)	The price and the amount of demand	Salehi Amiri and et al (2020) Sebatjane Makoena, Adetunji Olufemi (2020) Jouzdani Javid, Govindan Kannan (2020) Xueli (2019) Yavari Mohammad, Mohaddese Geraeli (2019) Chen Shuo et al (2019) Santos (2019) Wladimir et al (2017) Kaasgari et al (2016) Yousefi et al (2016) LeandroC.Coelho, Gilbert Laporte (2014) M.A.H. van Elzakkera et al (2014)
Attention to the land	Paciarotti and Torregiani (2021) Saavedra et al (2018) Yousefi et al (2016)	The level of social responsibility	Raj et al (2018) Mathivathanana et al (2017)	The cost of distribution	Das Kanchan (2018) M.A.H. van Elzakkera et al (2014)
Attention to energy	Paciarotti and Torregiani (2021) Kamble Sachin.S et al (2019) Jadhav et al (2018)	Creating jobs	Santos (2019) Kamble Sachin.S et al (2019) Saavedra et al (2018) Gómez-Luciano Cristino Alberto et al (2018) TejaMalladi Krishna, Sowlati Taraneh, (2018)	Number of products	Chen Shuo et al (2019)

Indicators for Sustainable Supply Chain					
Environmental	**Researchers**	**Social**	**Researchers**	**Economic**	**Researchers**
	Das Kanchan (2018) Giang N. T. Nguyen, Tapan Sarker (2018)				
Attention to the animals	Paciarotti and Torregiani (2021)	The impact of the Corona virus ۱۹on GDP	Taghikhai and et al (2021)	The number of suppliers	Das Kanchan (2018)
renewable energy	Biuki and et al (2021) Jadhav et al (2018) Yousefi et al (2016) Janssen Larissa et al (2016)	Justice	Paciarotti and Torregiani (2021) Gómez-Luciano Cristino Alberto et al (2018)	The cost of supplying organic raw food	Mirhedayatian and et al (2014) Santos (2019) M.A.H. van Elzakkera et al (2014)
Environmental pollution	Biuki and et al (2021) Moreno-Camacho Carlos et al (2019) Giang N. T. Nguyen, Tapan Sarker (2018)	The effect of the Corona virus ۱۹on the rise of unemployment	Taghikhai and et al (2021)	Supplier's fee	Mirhedayatian and et al (2014)
Waste Management	Arkajyoti De, Surya PrakashSingh (2020) TejaMalladi Krishna, Sowlati Taraneh, (2018) Janssen Larissa et al (2016) M.A.H. van Elzakkera et al (2014)	working conditions	Moreno-Camacho Carlos et al (2019)	service fee	Mirhedayatian and et al (2014)
Environmental effects of production	Yavari Mohammad, Mohaddese Geraeli (2019) Ahmed Mohammed , QianWang (2017)	Customer Social Pressure	Mani Venkatesh a, Gunasekaran Angappa (2018) Mathivathanana et al (2017)	Cost of Route Custom Supply Products (Delivery Time / Start and End)	Biuki and et al (2021) Xueli (2019) Mirmajlesi Seyed Reza, Shafaei Rasoul (2016)

Therefore, after reviewing and studying the articles, a guided interview was conducted in this field with the relevant officials of the studied companies and university professors in order to fully understand all the indicators of the research, and it was distributed among these people through a checklist (which is presented in the appendix), indicators which had the most points were selected and considered as input, intermediate and output indicators, and finally the final indicators were determined, which are explained in the following.

The supply chain management process studied by the research

Supply chain management can be defined as "a set of approaches used to optimally combine suppliers, manufacturers, distributors and stores (retailers)", so that products are supplied in sufficient quantities and at the right time, in order to minimize system costs, and customer satisfaction should also be obtained in this chain. Therefore, according to this definition, the supply chain management process studied in the research is shown in Figure (1):

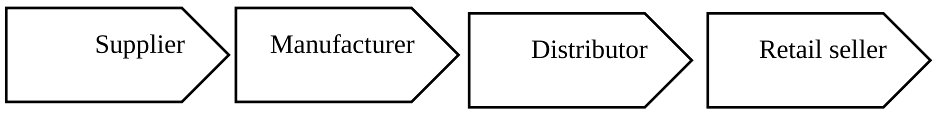

Figure 1. Supply chain management process

The details of this model according to the input, output and intermediary indicators studied in the research are presented and explained.

Model Building

This study, inspired by the network DEA model presented in the study of Shafii and Ghotbi[2] (2020) and Shamsi Jamkhane et al[3]. (2020), presents a model in which input and output variables and intermediaries will be considered with a sustainable approach. The differences and advantages of the proposed model in comparison with the above models can be summarized as follows:

1. The mentioned models were two-stage and three-stage, but the proposed model presented in this research will examine four consecutive stages of supply, production, distribution and distribution of perishable products, which is more compatible with the nature of the activities of active units in dairy and meat and protein production factories.
2. Some desirable outputs at the end of each stage are included in the model, which play a significant role in perishable products performance measurement. These outputs are independent and leave the system and, in other words, do not enter the next stage.
3. Excess inputs are also considered in each step, in addition to the intermediate inputs that were the outputs of the previous step, which play a very important and essential role in the supply, production, distribution and distribution of perishable products.

Therefore, the proposed model in this research is presented as Figure (2) based on this:

2 Shafiee. M, Ghotbi. M, (2020).

3 Shamsi Jamkhaneh A, Rahmani Perchklaei B, Hosseinzadeh Lotfi F, Hadji Molana S M. (2020).

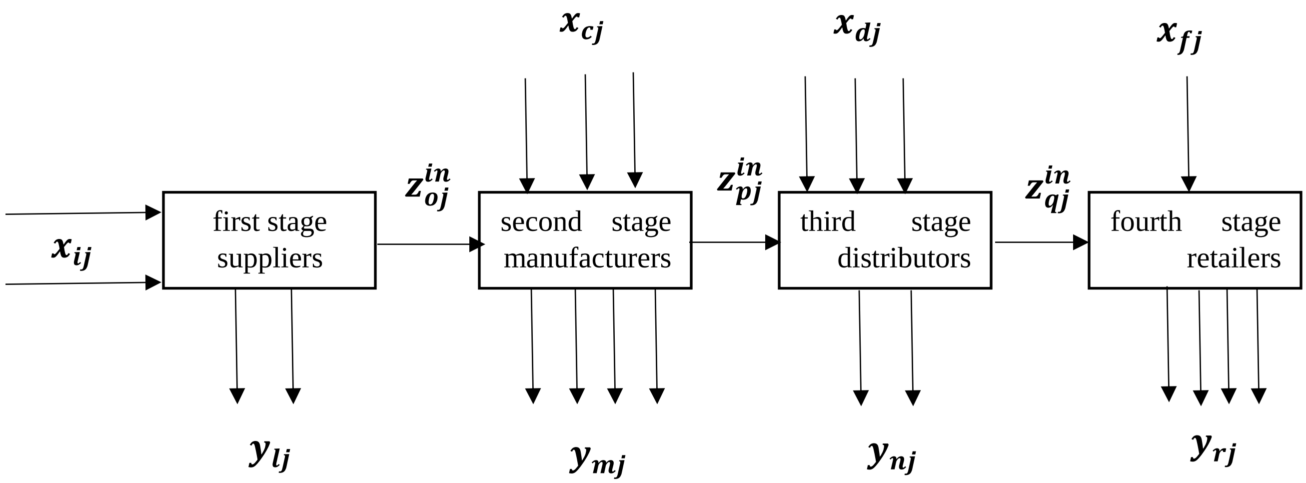

Figure (2): The proposed general model with four consecutive steps

According to figure (2), there are n decision-making units DMUj (j=1…..n) which in the first stage have m input variables (i=1…..m) xij, which generate q output which a part of these outputs enter the second stage as the input variable of the second stagez_{oj}^{in} (o=1…..O), and the other part does not enter the second stage of the units process, which is denoted by the symbol y_{lj} (l=1…..L). In the second stage, in addition to the variables received from the first step, there are also other input variables, which are not generated from the previous step and are displayed as x_{cj} (c=1....C). In this stage too, part of the output enters the third stage as the input variable of the third stage z_{pj}^{in} (p=1…..P), and another part does not enter the third stage of the unit process, which is denoted by the symboly_{mj} (m=1….. M). In the third stage, like the second stage, in addition to the variables received from the second stage, there are other input variables that are not produced from the previous stage, and it is displayed as x_{dj} (d=1...D).

In this stage too, part of the output enters the fourth stage as the input variable of the fourth stage z_{qj}^{in} (q=1…..Q), and another part does not enter the third stage of the unit process, which is indicated by the symboly_{nj} (n =1…..N). In the fourth stage, like the previous stages, in addition to the variables received from the third stage, there are also other input variables, which are not produced from the previous stage, and it is displayed as x_{fj} (f=1...F) and finally, the final output is displayed as y_{rj} (r=1…..s).

Efficiency in DEA

Efficiency in DEA is defined as the ratio of the weighted sum of outputs to inputs. Therefore, according to this definition, the efficiency of the three steps can be defined in the form of table (2):

Table 2.
The concept of efficiency in the four stages of the NDEA model in the research

first stage efficiency	Second stage efficiency	Third stage efficiency	Fourth stage efficiency
$\theta_j^1 = \frac{\sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{l=1}^{L} u_l y_{lj}}{\sum_{i=1}^{m} v_i x_{ij}}$	$\theta_j^2 = \frac{\sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{m=1}^{M} u_m y_{mj}}{\sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{c=1}^{C} v_c x_{cj}}$	$\theta_j^3 = \frac{\sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{n=1}^{N} u_n y_{nj}}{\sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{d=1}^{D} v_d x_{dj}}$	$\theta_j^4 = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{f=1}^{F} v_f x_{fj}}$
u_o coefficient o Output variable u_l coefficient l Output variable v_i coefficient i Input variable	u_p coefficient p Output variable u_m coefficient m Output variable v_c coefficient c Input variable u_o coefficient o Input variable	u_q coefficient q Output variable u_n coefficient n Output variable v_d coefficient d Input variable u_p coefficient p Input variable	u_r coefficient r Output variable v_f coefficient f Output variable u_q coefficient q Input variable

Total efficiency model of Network Data Envelopment Analysis (DEA)

The total fractional model of the two-stage system can be written as model (1) under the constant return to scale (CRS) and input-oriented model assumptions:

Model (1):

$$\theta_0 = \frac{\sum_{o=1}^{O} u_o z_{o.}^{in} + \sum_{l=1}^{L} u_l y_{l.} + \sum_{p=1}^{P} u_p z_{p.}^{in} + \sum_{m=1}^{M} u_m y_{m.} + \sum_{q=1}^{Q} u_q z_{q.}^{in} + \sum_{n=1}^{N} u_n y_{n.} + \sum_{r=1}^{s} u_r y_{r.}}{\sum_{i=1}^{m} v_i x_{i.} + \sum_{o=1}^{O} u_o z_{o.}^{in} + \sum_{c=1}^{C} v_c x_{c.} + \sum_{p=1}^{P} u_p z_{p.}^{in} + \sum_{d=1}^{D} v_d x_{d.} + \sum_{q=1}^{Q} u_q z_{q.}^{in} + \sum_{f=1}^{F} v_f x_{f.}}$$

S.t:

$$\frac{\sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{l=1}^{L} u_l y_{lj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \text{ , j=1……n}$$

$$\frac{\sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{m=1}^{M} u_m y_{mj}}{\sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{c=1}^{C} v_c x_{cj}} \leq 1 \text{ , j=1……n}$$

$$\frac{\sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{n=1}^{N} u_n y_{nj}}{\sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{d=1}^{D} v_d x_{dj}} \leq 1, j = 1 \dots \dots n$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{f=1}^{F} v_f x_{fj}} \leq 1, j = 1 \dots \dots n$$

v_i: i=1…..m), v_c: c=1…..C), v_d: d=1…..D), v_f: f=1…..F), u_o: o=1…..O), u_l: l=1…..L), u_m: m=1…..M), u_n:(n=1…..N), u_p :(p=1…..P), u_q:(q=1…..Q), u_r:(r=1…..s)

Considering that model (1) is a fractional model, it can be converted into a linear programming format using the proposed methods, which is described in model (2):

Model (2):

$$\theta_0 = \sum_{o=1}^{O} u_o z_{o.}^{in} + \sum_{l=1}^{L} u_l\, y_{l.} + \sum_{p=1}^{P} u_p z_{p.}^{in} + \sum_{m=1}^{M} u_m\, y_{m.} + \sum_{q=1}^{Q} u_q z_{q.}^{in} + \sum_{n=1}^{N} u_n\, y_{n.} + \sum_{r=1}^{s} u_r\, y_{r.}$$

S.t:

$$\left(\sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{l=1}^{L} u_l\, y_{lj}\right) - \sum_{i=1}^{m} v_i\, x_{ij} \le 0$$

$$\left(\sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{m=1}^{M} u_m\, y_{mj}\right) - \left(\sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{c=1}^{C} v_c\, x_{cj}\right) \le 0$$

$$\left(\sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{n=1}^{N} u_n\, y_{nj}\right) - \left(\sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{d=1}^{D} v_d\, x_{dj}\right) \le 0$$

$$\left(\sum_{r=1}^{s} u_r\, y_{rj}\right) - \left(\sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{f=1}^{F} v_f\, x_{fj}\right) \le 0$$

$$\sum_{i=1}^{m} v_i\, x_{ij} + \sum_{o=1}^{O} u_o z_{oj}^{in} + \sum_{c=1}^{C} v_c\, x_{cj}) + \sum_{p=1}^{P} u_p z_{pj}^{in} + \sum_{d=1}^{D} v_d\, x_{dj} + \sum_{q=1}^{Q} u_q z_{qj}^{in} + \sum_{f=1}^{F} v_f\, x_{fj} = 1$$

v_i:(i=1…..m), v_c:(c=1…..C), v_d:(d=1…..D), v_f:(f=1…..F), u_o:(o=1…..O), u_l:(l=1…..L), u_m:(m=1…..M), u_n:(n=1…..N), u_p :(p=1…..P), u_q:(q=1…..Q), u_r:(r=1…..s)

After specifying the model and the input and output indicators of each stage, the necessary data of each indicator was determined and entered into model (2), and the efficiency evaluation of each of the decision-making units studied in the research was solved with WinQsb, the results of which are given in full. It has been in the fourth chapter.

Selection of Indicators

The requirement to calculate the efficiency of the supply chain is to first provide the input and output indicators of the data coverage analysis model, for this purpose the selected input and output indicators were determined according to table (1) and also the opinion of the relevant experts and by providing the checklist, and the efficiency results of each of these The supply chains were determined after entering the index values into the winQsb, which is described below:

Input variables are the factors that the efficiency decreases by adding one unit of it to the system and by assuming the other conditions to be constant.

Outputs variables are the factors that the efficiency increases by adding one unit of it to the system and by assuming the other conditions to be constant.

One of the determining factors in achieving reliable and appropriate results in the assessment is the accurate and appropriate selection of inputs and outputs. Different criteria should be considered to select the appropriate input and output variables. For this purpose, extensive field and library studies were conducted on variables and indicators in the field of various supply chain activities in order to identify and extract effective input and output and intermediate indicators in order to calculate the relative efficiency of the supply chain in the sector of suppliers, manufacturers, distributors and retailers, and after review and study of the articles, a list of effective indicators was prepared in order to fully understand all the research indicators, the description of which is given in table (1). Then, the most important indicators that are effective in evaluating the efficiency of the supply chain were selected according to the number of indicators with the opinion of the company's experts and providing a checklist about the importance of the indicators in table (1), and they were entered into the network DEA model of the research, which is given below:

Input indicators in the 1st stage (suppliers)

The cost of providing raw organic food (economic-environmental)

Transportation cost due to road congestion and perishability of products (economic)

Output indicators in the 1st stage (suppliers)

Supplier fee (economic-social)

Labor force safety percentage in terms of HSE (social)

PPM without defects (economical)

Input indicators in the 2st stage (producers)

PPM without defects (economical)

Cost of advertising marketing campaigns (economical)

The cost of environmentally sustainable choices in all stages of production (economic)

Freshness index of the inventory of received materials at time T (economic)

Output indicators in the 2st stage (producers)

Percentage of attention to reducing CO2 emissions (environmental)

Freshness-dependence rate (environmental)

Percentage of attention to food waste (environmental)

Average credit factor (social)

Number of green products (green production) (environmental)

Input indicators in the 3st stage (distributors)

Number of green products (green production) (environmental()

The cost of innovative distribution systems (economical)

Rights of workers and employees (economic-social)

Routing cost of the supply chain of perishable products (delivery time/start and end) (Economic)

Output indicators in the 3st stage (distributors)

Variety of services (economic)

Percentage of attention to the number of perishable items (types of spoiled food products) (environmental)

Percentage of useful life of distributed processing stock (economic)

Input indicators in the 4st stage (retailer)

Percentage of useful life of distributed processing stock (economic)

Cost of services (economic)

Output indicators in the 4st stage (retailer)

Percentage of customer satisfaction (social)

Satisfaction percentage of workers and employees (social)

Percentage of attention to return product (environmental)

Average credit factor in local markets (social)

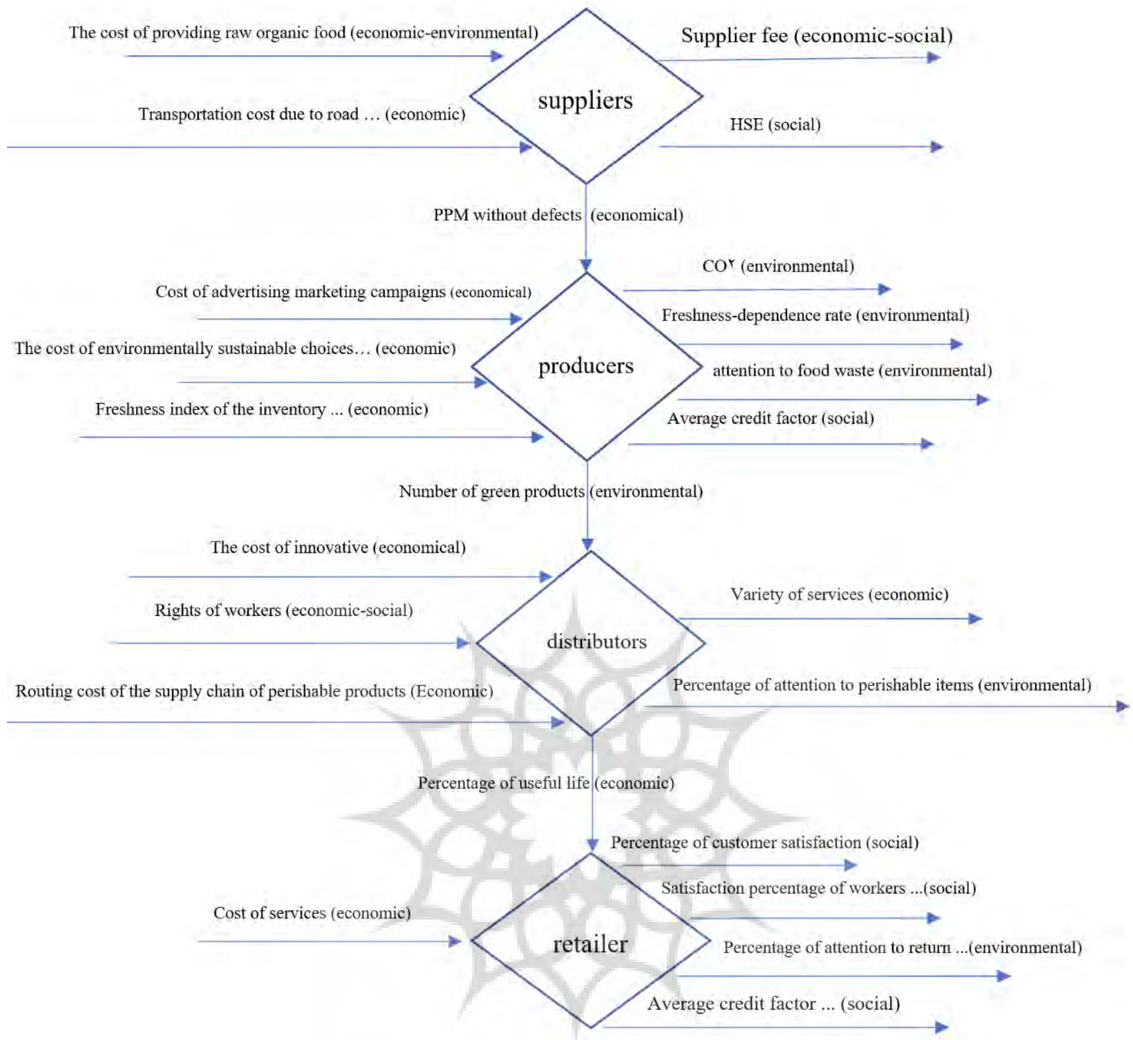

Figure (3): Sustainable supply chain of perishable products

Therefore, in general, the process of using these indicators is given in the general model of Figure (3). Also, after specifying the indicators, it is necessary to specify the necessary data in order to calculate the efficiency according to the indicators, which is given below.

Findings

After determining the input and output indicators, by substituting these values in the model (2) which was explained, the model was solved and the efficiency of each supply chain was checked, the results of which are listed in table (3).

Table 3.
The results of evaluating the efficiency of the supply chains evaluated in the research

DMU	θ_1	θ_2	θ_3	θ_4	θ^*
DMU1	0.9595	1	0.9375	1	0.993
DMU2	0.938	1	1	0.9953	1
DMU3	1	1	1	1	1
DMU4	1	1	1	1	1

DMU5	0.9213	0.9896	1	0.9268	0.9822
DMU6	1	1	1	1	1
DMU7	1	1	1	1	1
DMU8	0.9925	1	0.9532	1	1
DMU8	1	1	0.9936	0.9064	1
DMU10	0.9421	1	0.9917	0.9769	1
DMU11	0.9609	0.9859	0.9924	1	0.9859
DMU12	0.9493	1	0.9939	0.9190	0.9886
DMU13	0.8620	1	1	0.9604	1
DMU14	0.8896	0.9589	0.9856	0.9397	0.9545
DMU15	0.9615	0.9449	1	1	1
DMU16	1	0.9393	1	0.9719	1
DMU17	1	1	0.9778	0.8806	1
DMU18	0.9646	1	1	0.9960	1

According to the results of calculation:
The results of numerical efficiency are between zero and one, and the units below one are inefficient and the efficient units have their efficiency equal to one.
The supply chain of DMU3, DMU4, DMU6, DMU7, DMU8, DMU16, DMU17 companies are efficient in the first stage, supply of raw materials needed for production, in the financial year under study.
The supply chain of DMU1, DMU2, DMU3, DMU4, DMU6, DMU7, DMU8, DMU8, DMU10, DMU12, DMU13, DMU17, DMU18 companies are efficient in the second stage, production of dairy, meat and protein products, with a look at perishable products in the financial year under study.
The supply chain of DMU2, DMU3, DMU4, DMU6, DMU7, DMU5, DMU13, DMU15, DMU16, DMU18 companies are efficient in the third stage, distribution of perishable products, in the financial year under study.
The supply chain of DMU1, DMU3, DMU4, DMU6, DMU7, DMU8, DMU11, DMU15 companies are efficient in the fourth stage, retail of perishable products, in the financial year under study.
In general, the supply chain of DMU2, DMU3, DMU4, DMU6, DMU7, DMU8, DMU8, DMU10, DMU13, DMU15, DMU16, DMU17, DMU18 companies are efficient by obtaining an efficiency score of one in the financial year under study.
Also, the supply chain of perishable products of DMU3, DMU4, DMU6, DMU7 companies are efficient in all stages and in general, which shows the effective relationship of these companies between all parts of their supply chain, i.e. suppliers, manufacturers and distributors and retail of perishable products in the financial year studied.
The supply chain of DMU1, DMU2, DMU5, DMU8, DMU10, DMU11, DMU12, DMU13, DMU14, DMU15, DMU18 companies are inefficient. In the first stage, supply of raw materials needed for production in the financial year under study.
The supply chain of DMU5, DMU11, DMU14, DMU15, DMU16 companies are inefficient in the second stage, production of dairy, meat and protein products, with a look at perishable products in the financial year under study.
The supply chain of DMU1, DMU8, DMU8, DMU10, DMU11, DMU12, DMU13, DMU14, DMU17 companies are ineffective in the third stage, the distribution of perishable products in the financial year under study.
The supply chain of DMU2, DMU5, DMU8, DMU10, DMU12, DMU13, DMU14, DMU16, DMU17, DMU18 companies are ineffective in the fourth stage, retail of perishable products in the financial year under study.
In general, the supply chain of companies DMU1, DMU5, DMU11, DMU12, DMU14

are inefficient in the financial year under study due to the efficiency score of less than one.

Conclusion

The results of the calculations show that we can analyze the efficiency of all the perishable products companies studied in the research, which we describe below:

Table 4.
Investigating the supply chain efficiency of DMU1 Company

DMU	θ_1	θ_2	θ_3	θ_4	θ^*
DMU 1	0.9595	1	0.9375	1	0.9993

According to the results of solving the model and determining the efficiency of DMU1, this company is not efficient in the third and overall stages. Also, it should be mentioned that despite 100% efficiency in the production process of perishable products and 100% efficiency in the sales process, the overall efficiency of this company has decreased to 9993%, which can be attributed to the low efficiency score of the raw material supply process and distribution of perishable products. Therefore, the need to invest in these inefficient areas is felt more than before.

Table 5.
Investigating the efficiency of the supply chain of DMU5 Company

DMU	θ_1	θ_2	θ_3	θ_4	θ^*
DMU 5	0.9213	0.9896	1	0.9268	0.9822

The results of solving the model and determining the efficiency of the DMU5 company show that this company is not efficient in the first, second, fourth and overall stages. Also, it should be mentioned that, despite the 100% efficiency in the process of distributing perishable products, the overall efficiency of this company has decreased to 9822%, which can be attributed to the low efficiency score of the process of supplying the required raw materials and production and sales of the perishable products. Therefore, the need to invest in these inefficient areas is felt more than before.

Table 6.
Investigating the supply chain efficiency of DMU11 Company

DMU	θ_1	θ_2	θ_3	θ_4	θ^*
DMU 11	0.9609	0.9959	0.9924	1	0.9859

The results of solving the model and determining the efficiency of DMU11 show that this company is not efficient in the first, second, third and overall stages. Also, it should be mentioned that despite 100% efficiency in the process of selling perishable products, the overall efficiency of this company has decreased to 9859% that can be attributed to the low efficiency score of the process of supplying the required raw materials and the production and distribution of perishable products. Therefore, the need to invest in these inefficient areas is felt more than before.

Table 7.
Investigating the supply chain efficiency of DMU12 Company

DMU	θ_1	θ_2	θ_3	θ_4	θ^*
DMU 12	0.9493	1	0.9939	0.9190	0.9886

The results of solving the model and determining the efficiency of DMU12 show that this company is not efficient in the first, third, fourth and overall stages. It should also be mentioned that, despite 100% efficiency in the process of producing perishable products, the overall efficiency of this company is decreased to 0.9886%, which can be attributed to the low efficiency of the process of supplying the required raw materials and distributing and selling perishable products. Therefore, the need to invest in these inefficient areas is felt more than before.

Table 8.
Investigating the supply chain efficiency of DMU14 Company

DMU	θ_1	θ_2	θ_3	θ_4	θ^*
DMU 14	0.8896	0.9589	0.9856	0.9397	0.9545

The results of solving the model and determining the efficiency of DMU14 show that this company is not efficient in the first, second, third, fourth and overall stages; And the overall efficiency of this company has decreased to 0.9545%, which can be attributed to the low efficiency score of the process of supplying the required raw materials and producing, distributing and selling perishable products. Therefore, the need to invest in these inefficient areas is felt more than before.

Also, the results of Table (3) and Figure (4) show that the average efficiency of the supply chain for the production and distribution of perishable products in the financial year studied by the research in the suppliers sector was equal to 0.9634%. This average was equal to 0.9899 in the producers' sector, 0.9903 in the distributors' sector, and 0.9707 in the retailers' sector. Therefore, the average efficiency in figure (4) shows that the most inefficiency problems of the studied companies are related to the supplier sector. Also, the overall average efficiency is equal to 0.9950.

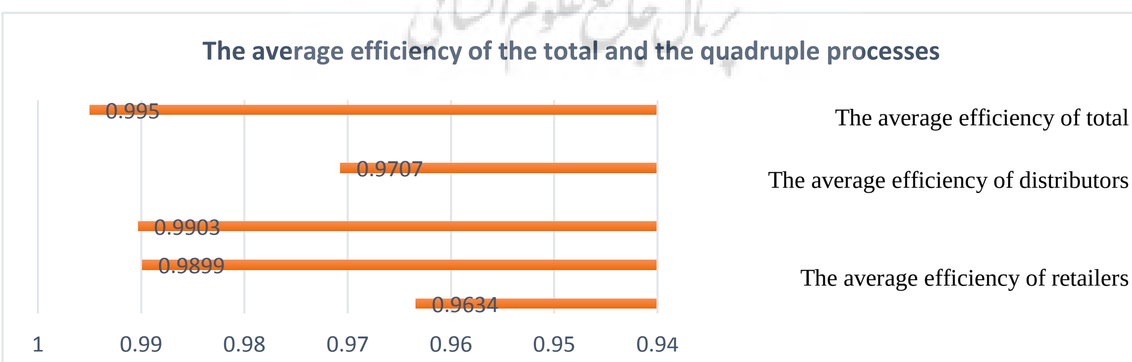

Figure (4): The average scores of total efficiency, the processes of supply, production, distribution and sale of perishable products

According to Figure (4), among the supply chain of 18 companies of perishable products studied in the research, the process of suppliers has lower efficiency scores than the processes of production, distribution and sale, which is therefore suggested; Inefficient companies at each stage have taken action to identify their inefficiency factors in the processes of production, distribution and sale of perishable products by modeling the performance of efficient companies, and in this way, improve the efficiency of each stage and their overall efficiency.

Research suggestion for future research

According to the results of solving the model, determining the efficiency of DMUs and results of evaluating the efficiency of the supply chains evaluated in the research, we present the following suggestions for future research:

- Attention to reasons that are not efficient in the raw material supply process.
- Special attention to social dimension, in modeling the least attention to the social dimension becomes.
- Using new parameters for the suppliers of perishable products.
- Modeling based of Transportation cost due to road congestion and perishability of products.

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