



Modeling and simulation of supply chain resilience for unnecessary perishable foods using an agent-based modeling approach

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Abstract

The new challenge for business managers is to model and simulate an efficient and effective perishable foods supply chain network that is resilient enough to deal with different disruptions. Therefore, this research aims to model a resilient supply chain for unnecessary perishable foods using an agent-based simulation to deal with future disruptions. To confirm the strategies and model, the statistical population and sample include 7 prominent university professors and 11 managers of various departments of companies producing perishable foods (sales department; production department; planning and warehouse department; laboratory and quality control department; and commercial department). NetLogo software has been utilized to test the agent-based model. The simulation environment in this study includes the behavior and interactions between the members of the supply chain of unnecessary perishable foods and the consumers in Shiraz City. The simulation results indicate that the use of strategies such as consumer behavior tracking, discount, awareness of product safety, robotics, the use of blockchain among the levels of distributors and retailers, and the activation of several supporting suppliers, leads to a resilience supply chain of unnecessary perishable foods under different disruptions. In addition, among the different scenarios, the 30% discount and 40% robotics have been the most effective in the resilience of the supply chain of unnecessary perishable foods under different disruptions.

Keywords: Modeling and simulation, supply chain resilience, unnecessary perishable foods, Agent-based modeling

Paper Type: Original Research

1. Introduction

The COVID-19 pandemic is unprecedented in modern history, and the resulting disruptions have had deep effects on the performance of global supply chains in both upstream and downstream operations (Nikolopoulos et al., 2021). Although companies usually have contingency plans, few have anticipated the possibility of a pandemic or coping with its variants and the longevity of pandemic disruptions (Hobbs, 2020). In the current context, COVID-19 has led to a worsening of the performance of perishable goods supply chains in terms of trade, cost, priorities, and future opportunities (Barbieri et al., 2020). Due to rising global temperatures and quarantine periods during the COVID-19 pandemic, many perishable products and temperature-sensitive (such as fresh fruits, vegetables, meat and seafood, etc.) were wasted (Kumar et al., 2022). Different levels of the supply chain of perishable goods, including suppliers, manufacturers, distributors, retailers, and customers, have all been the main victims of COVID-19 (Kumar et al., 2022; Sharma et al., 2022). Supply, demand, production, transportation and logistics, retailing, relationships between stakeholders of perishable goods, and financial stability have all been seriously affected by the COVID-19 pandemic (Zhao et al., 2023). In addition, families' need for essential products like fresh food, dairy, and medicine has risen, while the need for unessential products such as frozen food, canned goods, snacks, and chocolate has decreased. The decrease in demand for unessential products is due to a decrease in people's shopping power as most of them lost their jobs during the outbreak of the pandemic. Therefore, they prefer to spend their savings on essential items rather than spending it on unnecessary items (Murmur et al., 2023). The design of a supply chain of perishable products in the conditions of special disturbances should be considered according to the specific characteristics of the chain, which includes various decisions such as locating facilities, finding the best routes, balancing production rates, and storing and selling products (Abbasian et al., 2023). Building resilience is an effective way to help perishable goods supply chains recover from specific disruptions (Zhao et al., 2023). Following the severe disruption caused by the coronavirus pandemic, manufacturing companies have taken steps to change their supply chain strategies to achieve a resilient chain with customers, suppliers, and other stakeholders. Therefore, the new challenge for business managers is to create an efficient and acceptable supply chain network that is resilient enough to recover from any disturbance (D'Adamo & Lupi, 2021). The

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resilience of the supply chain is the ability of the supply chain to cope with the outcomes of risky events to return to the initial conditions or reach a more optimal condition after the disruption (Ganguly et al., 2018). A strategic plan including preparedness, response, and recovery can more effectively reduce the effects of specific disruptions such as COVID-19 on supply chains. Therefore, considering all three stages of preparation, response, and recovery for supply chain resilience can be challenging. If the supply chain resilience strategy is to be proactive in preparing for future disruption, for preparedness, if it can help supply chain members react quickly and minimize the immediate impact, for respond and if it can help the supply chain to return to the original state or even better, it is considered for recovery (Chowdhury et al., 2021). According to the content mentioned above since there are many components in the resilience of the supply chain of perishable foods which dynamically relate to each other and the environment outside the system, small changes in one part can have huge effects on the chain. This means that the action of each factor is a function of the behavior of other factors, which cause the complexity of the supply chain analysis and cannot be modeled. Therefore, in projects that require solving and controlling complex problems, decomposing decision-making into a factor's arguments and unraveling problems through discussion is understood as an unusual kind of exploratory trouble-solving and the general action of the system is the result of the action of individual agents; As a result, it seems that the appropriate model of the current research is agent-based. Hence, according to the goal of this research, which is to design a resilient supply chain for unnecessary perishable foods under different disruptions, the researcher is looking for answers to the following questions:

RQ 1) What are the features of the model of supply chain resilience for unnecessary perishable foods using an Agent-based modeling approach to cope with different disruptions?

RQ2) Who are the agents in the simulation space, how do they interact with each other and what effect do they have on the resilience of the model?

RQ 3) What strategies are there for the resilience of the supply chain of unnecessary perishable foods under different disruptions and how can they be implemented?.

Also, the main unique contributions and innovations of the current manuscript are as follows:

Considering the research gap, the innovation of this manuscript is focused on modeling and simulating the agent-based model of the resilient supply chain for unnecessary perishable foods such as beverages and canned foods under different disruptions. In addition, in this manuscript, all particular disruptions available together such as changing consumer behavior (macro level) and demand, supply, production, logistics, finance, and information (micro level) have been evaluated. Moreover, in this manuscript, for the first time, the impact of using different strategies such as discounts, awareness of product safety, and the activation of several supporting suppliers, etc. has been investigated in the interactions between agents (manufacturers, customers, etc.).

2. Research background

Khan & Ali (2023) evaluated the strategies to increase the quality and resilience of the cold supply chain during the outbreak of Coronavirus. For this target, first by reviewing the research literature, disorders related to Covid-19 and resilience strategies in the cold supply chain were identified, then they were analyzed through the fuzzy quality function deployment (QFD) technique. The results showed that "crisis simulation", "identification and securing of logistics" and "cold supply chain digitization" are the three best strategies to guarantee the resilience of the cold supply chain during the outbreak of Coronavirus. Ali et al. (2023) investigated how developing and developed agricultural products supply chain SMEs have been disrupted by the risk posed by COVID-19 and what useful measures have been considered for the resilience of the supply chain of agricultural products. Therefore, 24 semi-structured interviews including two developing countries (Pakistan and Tanzania) and one developed country (Australia) were used. The results of interviews with respondents from developed countries showed that close cooperation and frequent exchange of information between SMEs and government organizations is the key source of the resilience of the supply chain of agricultural products versus disorders caused by COVID-19. Zhao et al. (2023) investigated resilience strategies of the food-agriculture supply chain to get ready, answer, recover, and compliance with an unexpected tension such as COVID-19. Data were collected from interviews with food-agriculture supply chain experts from China and Spain and then analyzed through thematic and comparative analysis. The results show that frequently discussed resilience strategies, such as cooperation, redundancy, flexibility, guidance, and innovation, are effective in the stages of preparation, answer, recovery, and adaptation related to the outbreak Coronavirus. However, the effects depend on the cultural worthiness orientations of each country. Mandal et al. (2023) discussed the role of Industry 5(I5) in the resilience of the food supply chain during the outbreak Coronavirus. According to an overview of 140 food corporations and using the FsQCA Approach technique, the impact of Industry 5 on the resilience of the food supply chain was confirmed. Based on their research results, they suggested that manufacturers use robots, digital twins, IoE, edge computing with federated learning, big data, and

artificial intelligence in the food manufacturing procedure and digitize their supply chain by enforcing blockchain to provide clarity, confidence, and consistency in the manufacturing procedure. Rimhanen et al. (2023) identified four critical components of food system resilience in the face of specific disruptions such as COVID-19. For this purpose, semi-structured interviews were conducted with Finnish food systems and security experts. The findings indicated that the four critical components of resilience include systemic thinking, redundancy, variety of production and associates, and buffering strategies. Shankar et al. (2022) to increase the resilience of perishable food supply chains during the outbreak of Coronavirus. First through interviews with experts, identified the effective factors related to supply chain disruptions (SC) in perishable food supply chains. Then, they used a hybrid method called G-DANP. The results showed that the factors of restrictions on imports and exports and fear of violating social distancing guidelines are the main factors of the "cause" group. Whereas, perishable product price changes, panic buying, and stockpiling are critical "effect" group factors that affect perishable product supply chains. Ozdemir et al. (2022) investigated the available solutions for the resilience of the supply chain in the British perishable products market. For this intention, by reviewing the research literature and using structural equation modeling, the conceptual model was developed. Data were gathered from 282 retail workers. The findings indicate that resilience activities have been influenced by the disorders caused by COVID-19. Despite using two active and reactive approaches, it was not enough to cover all disruptions to make the supply chain resilient. In addition, innovation, empowerment, robustness, and risk management respectively, are the considerably influential elements in resilience during crises caused by the Coronavirus. Kumar & Kumar Singh (2022) researched the influence of the recent pandemic on perishable food-agri supply chains. For this purpose, the effects of COVID-19 on perishable agricultural and food supply chains and possible strategies have been investigated through literature review and experts' opinions. Also, to rank the effects of the recent pandemic on supply chains of agricultural food, the best-worst method (BWM) has been used. Poor access and availability, high costs of production and distribution, uncertainty of supply and distribution, disruption of imports, and lack of confidence in international trade were five important influences of the recent pandemic on agricultural food supply chains. Also, supply chain cooperation, coordination between stakeholders, information sharing, digitalization of processes, and resource sharing were selected as the most important resilience strategies of food-agri supply chains. Chen and Pazhanizadeh (2022) designed a closed-loop supply chain network in the time-occurrence of certain disorders in production and distribution volume and buyer demand uncertainty for perishable goods. For this purpose, they proposed a mathematical model of mixed-integer. This mixed-integer model consists of three objective subordinates. Maximization of profit, delivery time minimization, and lost working days reduction were the first to third objective functions, respectively. The research results show that with the proposed meta-heuristic algorithm, in a reasonable time, a complete set of Pareto solutions can be achieved. Mishra et al. (2022) examined the impact of disruptions due to the recent pandemic and the role of resilience in agricultural supply chains as an operational excellence approach using the Situation-Action-Process (SAP) framework and the Learning-Action-Performance (LAP) framework. The results showed that due to quarantine actions after the recent pandemic, the resilience among actors in agricultural supply chains has worsened (SAP). Also, through different proactive and reactive methods such as cooperation, coordination, and information and communication technology, we can achieve resilience in supply, demand, and logistics (LAP). In addition, the most important challenge to maintaining operational excellence during the outbreak of COVID-19 is the lack of commitment and insufficient support from senior management towards resilience. Cariappa et al. (2022) analyzed the influences of quarantine caused by the epidemic on food loss and food waste by using interrupted time series. The results show that quarantine causes a remarkable shift in prices and excessive waste of food materials.

Table 1. Research literature on disruptions and various solutions

Reference	Methodology	Perishable foods supply chains under specific disruptions	Resilience strategies	Planning Dimension		
				Preparedness	Respond	Recovery
Khan & Ali (2023)	Fuzzy QFD	Economic losses + Lack of supply chain transparency	Crisis simulation + Securing of logistics + Digitization	-		
Ali et al., (2023)	Qualitative	Supply + Demand + Process disruption	Close cooperation + Frequent exchange of information	-	✓	-
Zhao et al., (2023)	Thematic & Comparative analysis	Information + Supply + Demand + Production disruption	Collaboration + Redundancy + Flexibility + Leadership + Innovation			
Mandal et al., (2023)	FsQCA Approach	Supply & Demand disruption + Health & Hygiene of workers	Collaborative robots + Digital-twins + IoE + Edge computing with Federated learning + Big data + Artificial intelligence	-	-	
Rimhanen et al., (2023)	Qualitative	Supply + Production & Demand disruption	Buffering strategies + variety of production and associates	✓	✓	-
Shanker et al., (2022)	G-DANP	Price Variation + Panic Buying and Stockpiling	Price Strategy	-	✓	-
Ozdemir et al., (2022)	Structural equations based on covariance	Resilience-Building Activities disruption	Innovation + Supplier Empowerment & Key Partners + Building Strong Relationships with Suppliers and Employees	-	-	
Kumar & Kumar Singh (2022)	Best-Worst Method (BWM)	Logistical + Operational + Socio-Economic + Financial disruption	Supply chain Collaboration + Coordination between the Stakeholders + Information Sharing + Resource Sharing	✓	✓	-
Chen & Peivandizadeh (2022)	A mixed-integer mathematical model	Production and capacity distribution disruption	Several transportation systems + Use of technology	✓	✓	-
Mishra et al., (2022)	SAP & LAP framework	Supply + Demand + Logistical disruption	Collaboration + Coordination + ICT Increase Production Capacity +	-		
Cariappa et al., (2022)	Interrupted time series analysis	Supply Disruption + Demand Decline + Prices Increase + Waste Increase	Access to Digital marketplace + Capacity Making on Wastage Management Procedure	-	✓	-

2.1. Mathematical model

As supported by the literature, no one of the previous studies has centralized on the modeling and simulation of the agent-based model of the resilient supply chain for unnecessary perishable foods under particular disruptions has not been done. Even though many studies have been conducted on necessary perishable foods such as dairy foods, vegetables, etc. (Zhu et al., (2020), Cariappa et al., (2022), Kumar & Kumar Singh (2022)) negligible regard has been paid to unnecessary perishable foods such as beverages, Cocoa, etc. (Chowdhury et al., (2022), Shofawati & Herianingrum (2023). Moreover, in most past surveys on perishable foods, only a few cases of special disturbances such as supply and demand disruptions have been concentrated (Zhu & Krikke (2020), Ali et al., (2023), Mandal et al., (2023)). To develop a resilient supply chain of unnecessary perishable foods, it is essential to appraise all particular disruptions in the change in consumer behavior (macro level) and demand, supply, production, logistical, financial, and information (micro level) that this assessment has not been accomplished until now. Also, crisis management strategies in the resilient supply chain of unnecessary perishable foods have not been completely developed. The original contributions of this study can be resumed as follows:

- Developing an agent-based model of a resilient supply chain for unnecessary perishable foods to have a strategy consistent with real-world assumptions in parallel with each disruption. This manuscript is the first to model agent-based resilient supply chains for unnecessary perishable foods under specific disruptions.
- Applying an integrated framework of different strategies such as discounts, awareness of product safety, and activation of several supporting suppliers to benefit from the synergistic effects between them and obtain the best results.
- Evaluating the impact of using different strategies such as discounts, awareness of product safety, and activation of several supporting suppliers, etc., in interactions between agents (Manufacturers, Customers, etc.).

3. Methods

In some parts of this research (identification of agents and validation of the model) due to the need for experts' opinions, the interview tool was used. The interview was conducted with 7 prominent university professors and 11 managers of various departments of companies producing perishable foods (sales department; production department; planning and warehouse department; laboratory and quality control department; and commercial department). Also, in the simulation section by agent-based modeling approach, data available in perishable foods production companies have been used for calculation and reporting.

3.1. Stages of Research

After literature extraction in the field of research, in the first stage, a research gap was specified (Figure 1). Then in the second stage, 7 categories of disruptions caused by the coronavirus outbreak in the supply chain of unnecessary perishable foods and different strategies for resilience were recognized. (Table 2). These 7 types of disruptions are included. 1) Fluctuations in the buyer's behavior, 2) buyer's demand fluctuations, 3) goods production fluctuations, 4) supply fluctuations, 5) information flow fluctuations, 6) transportation fluctuations, 7) financial fluctuations. Also, in the third step, the model including all the disorders and various solutions for the resilience of the supply chain of unnecessary perishable foods was approved by the experts (Figure 2). Moreover, in the four steps, preparing the simulation environment, the number of agents and interactions between them were distinguished. In the fifth step, the validation of the model was accomplished based on the relationships between input variables and output variables. Finally, to choose the best resilience strategies, the model was tested with real data.

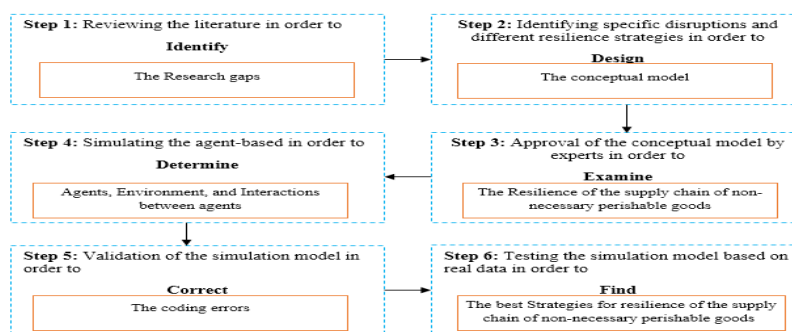


Figure 1. Research Steps

In Table 2, by rethinking the research literature, 7 types of critical disorders and different solutions for the resilience of the supply chain of unnecessary perishable food were identified. These critical disruptions are included. Fluctuations in the buyer's behavior, buyer's demand fluctuations, goods production fluctuations, supply fluctuations, information flow fluctuations, transportation fluctuations, and financial fluctuations. In addition, tracking changes in consumer behavior to predict product demand during a pandemic, purchase time preference (discount), awareness of product safety, automatic production systems (using robotics), buffering strategies (finding and activating multiple support suppliers), and use of blockchain were identified as resilience solutions.

Table 2. Determination disruptions and various solutions for the resilience of the supply chain of unnecessary perishable foods

Reference	Disruptions	Resilience strategies
Raj et al. (2022), Khan et al. (2022)	Macro-level fluctuations (change in consumer behavior)	Tracking changes in consumer behavior to predict product demand during a pandemic
Shafiei et al. (2022), Nikounam Nezami et al. (2023)	Demand fluctuations	Purchase time preference (discount)
Shi et al. (2020)		Awareness of product safety
Mor et al. (2022)	Production fluctuations	Automatic production systems (using robotics)
Ali et al. (2021)	Supply fluctuations	Buffering strategies (finding and activating multiple support suppliers)
Sharma et al. (2022), Kazancoglu et al. (2023)	Information fluctuations	Use of blockchain
Raj et al. (2022), Khan et al. (2022)	Transportation fluctuations	Use of digital technologies & blockchain
Gupta et al. (2023), Nikounam Nezami et al. (2023)	Financial fluctuations	Use of blockchain

In Figure 2, the conceptual model of the research was designed based on the research background and interviews with experts and was finally approved by the experts. First, in this model, 9 important agents of the supply chain of perishable foods involved in disruptions were appointed. Then, the disturbances related to each agent were specified, and the resilience management solutions were determined according to the disturbances. After that, the simulation implementation environment of Shiraz City, region 6 was determined. Finally, the order of coding the interactions between the agents was specified and finally, the model was implemented in the software with real data of 30 days.

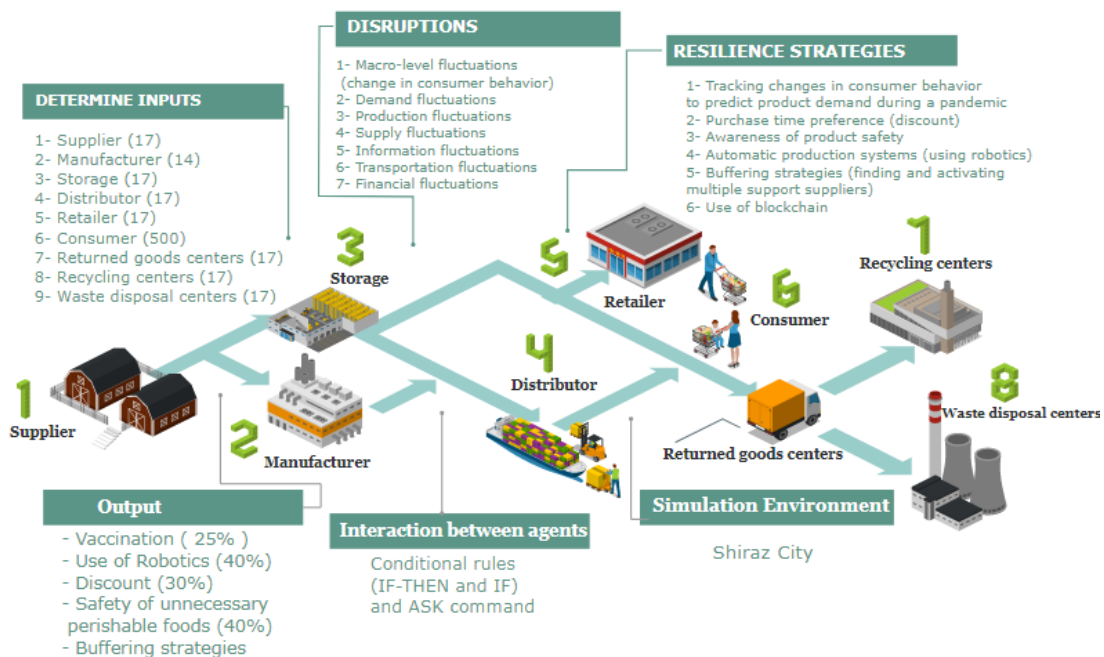


Figure 2. Conceptual model

4. Research findings

To implement the agent-based model NetLogo-6.3.0 software was utilized. To prepare the startup commands before beginning the simulation and running the model from the SETUP button and by using the GO button, this operation (interactions between agents) is started in the software. The simulation stop command is manually set to 120 ticks. Agents, environment, and interaction between agents were three basic parts of Agent-based modeling.

- **Agent of unnecessary perishable goods**

1) Supplier:

Specific disruptions with the unavailability of suppliers have created complications in the operations of the supply chain unnecessary perishable foods. This unavailability of suppliers can create randomness in supplier capacity. It is always assumed that the supplier can supply the ordered quantity, which is not the case in real-world scenarios, especially in the conditions of COVID-19.

2) Producer:

During the COVID-19 pandemic, producers cannot meet the continuous demand for perishable foods due to supply disruptions and the need to implement social distancing guidelines in production facilities. Limitations and uncertainty in delivery along with fluctuations in price, amount of raw materials required, and loss of labor leads to inconsistent supply.

3) Warehouses:

Appropriate refrigerator facilities such as cold storage are necessary to increase the life and reduce the waste of perishable foods. Therefore, the position becomes more problematic when storage is faced with quarantine scenarios caused by COVID-19. The situation becomes more challenging when warehouses are faced with quarantine scenarios caused by Covid-19. They must keep their goods intact for unlimited quarantine periods. With the increase of the quarantine period, the cost of keeping these goods in the warehouse has increased, which increases the sales price of the goods and consequently reduces the total interest. The rise in cost is due to increased maintenance efforts to keep the rate of deterioration under control. Also, with increasing efforts to maintain such goods, energy consumption increases, and as a result, environmental risks (CO₂ emission) increase.

4) Distributors:

Perishable goods such as cooked foods, dairy products, vaccines, and medicines are sensitive to temperature. Any slight fluctuation in the range of stable temperature causes chemical reactions and biological decay of goods. They become waste after a while. A disruption like the COVID-19 pandemic is a drastic threat to distributors in perishable supply chains.

5) Retailers:

The outbreak of the Coronavirus has faced retail supply chains of perishable foods with a series of new challenges, such as a significant decrease in demand for some perishable foods (unnecessary foods) and an increase in demand for others (necessary foods). The significant decrease in demand for unnecessary perishable foods has led to an increase in the accumulation of foods, an increase in expired foods in retail stores, and as a result, an increase in waste disposal and an increase in environmental risks (CO₂ emissions).

6) Consumers:

The COVID-19 virus has severely affected the behavior of consumers of perishable foods. Behavioral factors are one of the most effective factors affecting the supply chain of perishable foods during pandemics. Pandemics like COVID-19 have created an environment of heightened anxiety, fear, and uncertainty about the future. The results of the research show that consumers changed their consumption by 15-42% during the COVID-19 pandemic, depending on the type of perishable foods. Also, the number of times of buying and consuming perishable foods during the epidemic has changed significantly compared to before the epidemic.

7) Collection centers:

The Coronavirus pandemic has led to an impressive reduction in demand for perishable and unnecessary foods. A considerable decrease in unnecessary perishable foods has led to an increase in expired foods in retail sales and, as a result, an increase in the disruption in keeping perishable foods in return foods collection centers.

8) Recycling:

Quarantine policies during the Coronavirus crisis postponed the supply chain recycling transport because of the unavailability of labor to recycle foods for reuse. This has led to huge losses for the supply chains of perishable foods and subsequently negatively affected their performance.

9) Waste disposal:

The outbreak of the Coronavirus has led to a quick drop in demand for perishable and unnecessary foods. A quick decrease in the market for unnecessary perishable foods has led to an increase in the accumulation of expired foods, and as a result, a disruption in the disposal of perishable foods and an increase in environmental risks (CO2 emissions.)

• Environment

The simulation environment in this research is region 6 of Shiraz City.

• Interaction between agents

Conditional rules (IF-THEN and IF) and ASK command were employed for behavioral structures.

4. 1. Model execution results

In this scenario, the rate of outbreak of COVID-19 is 100%, and vaccination is 25%. Figures (3) and (4) illustrate the inputs and outputs.

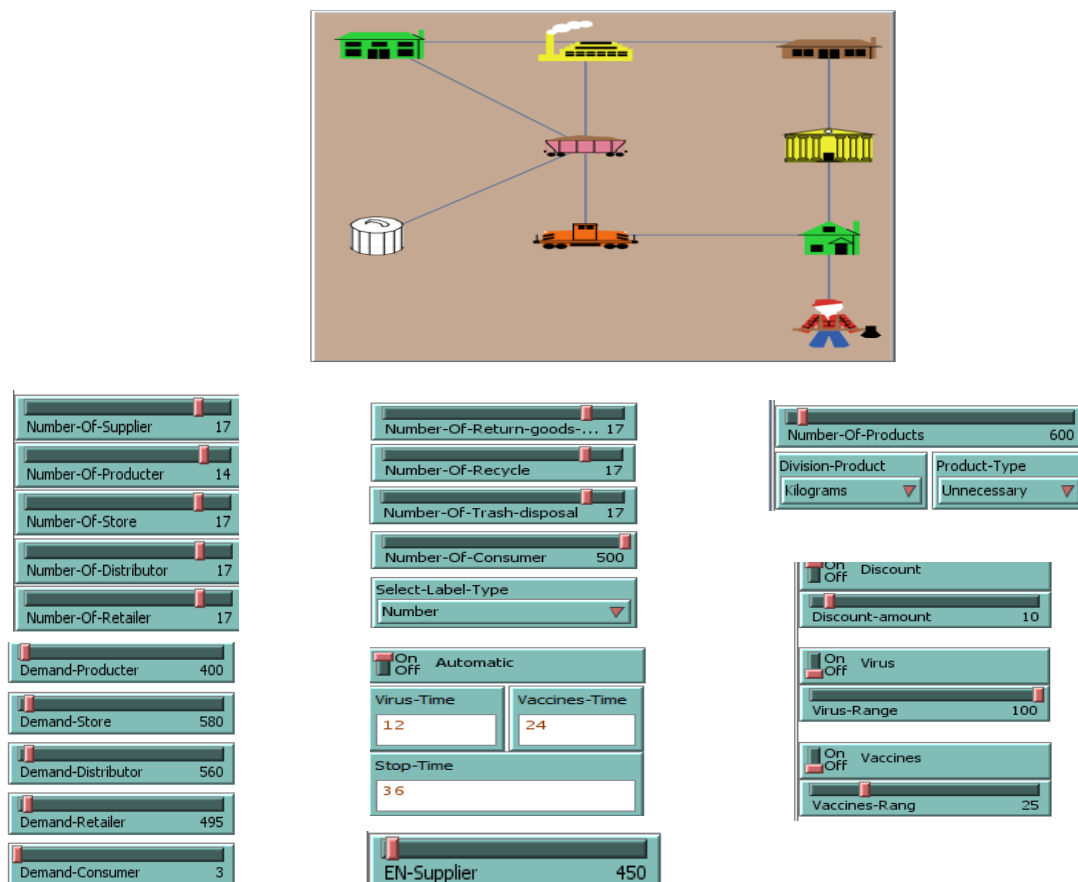


Figure 3. Inputs of agent-based model in NetLogo software

According to Figure 3, the inputs of the agent-based model include the color and number of each agent involved in the disorders of the supply chain of perishable foods, for example, 17 warehouses of foods with brown color, 14 manufacturers of foods with yellow color, 17 distributors with mustard color, etc., and the attributes of perishable foods, such as the unit and type of perishable foods (number and unnecessary perishable foods). The amount/number of demands for manufacturer (400 kg/number), storage (580 kg/number), distributor (560 kg/number), retailer (495 kg/number), and customers (3 kg/number) and the amount/number of supply for suppliers (450 kg/number). Also, On/Off switches include Coronavirus (On/Off), discounts (On/Off), and vaccination (On/Off). In addition, the percentage of each strategy is adjusted with a slider (decrease and increase) for example, the awareness of product safety (10% -100%), robotics (10% -100%), and the use of blockchain (10% -100%).

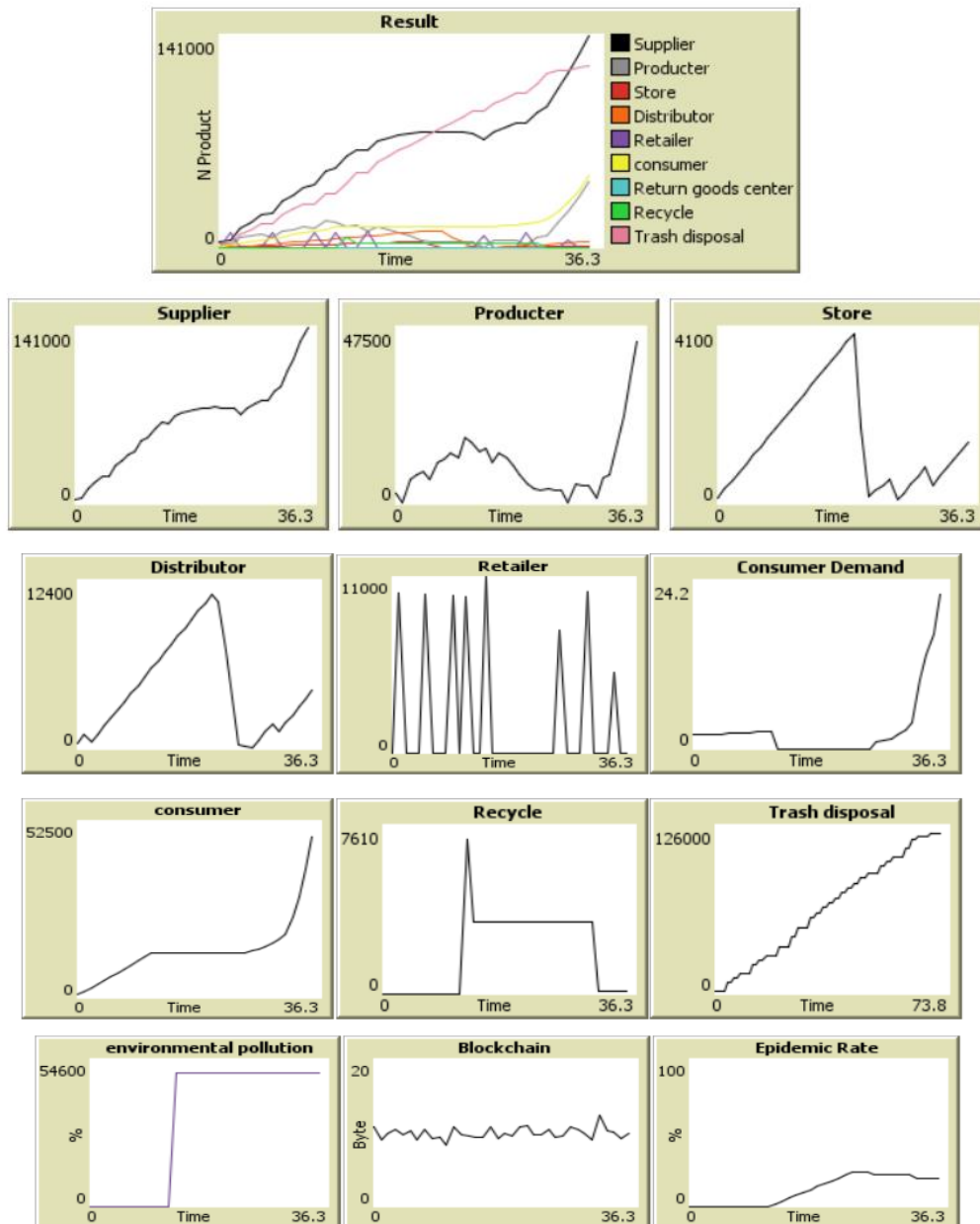


Figure 4. Outputs of agent-based model in NetLogo software

In outputs (Figure 4), the Coronavirus with an outbreak rate of 100 percent (the highest rate) has led to a sharp drop in shopping for unnecessary perishable foods in hyper-stores and supermarkets. The Coronavirus has severely affected the behavior of buyers of unnecessary perishable foods. Due to the decrease in household income and lack of subsidy, the tendency of households to consume unnecessary perishable food has decreased significantly. At the same time as the virus enters, the outbreak rate is 100%, 10% usage of robotics in manufacturing lines

(the lowest rate), 70% of the expiration range of foods (equal to 21 days), and 10% of the attention to the safety of perishable foods is used. We are confronting a sharp drop in consumer purchases and an upsurge in expired foods in hyper-stores and supermarkets (increase in stockpiling). Due to the sharp decrease in consumer demand and the return of food, there will be disruptions in the transportation and warehouse of the distributor. The lack of sufficient space to store perishable food leads to an increase in wastage and spoilage of food, as a result of which the cost of transportation, storage, and the cost of hiring new labor have increased significantly. Therefore, with a sharp decrease in demand, the economic costs of the supply chain include the costs of storing unnecessary perishable raw materials on the supplier side, and the final food products on the producer and distributor side, the social costs include the costs of hiring new labor and environmental costs including the costs of recycling, disposal and the waste of disinfectants, increased dramatically. In addition, before the entry of the COVID-19 virus into the model, the supply chain of perishable food was faced with 25% environmental pollution. With the arrival of the virus (100 percent) followed by a sharp decrease in demand and an increase in packaging waste and waste disposal, the level of environmental pollution reached 54 percent. To make the supply chain of unnecessary perishable foods resilient, we used different strategies, for this purpose from the tick of 12, we started vaccinations. By starting vaccination at the rate of 25% (the lowest), applying blockchain, utilizing robotics in the manufacturing line (40%), discount (30%), and attention to the safety of perishable foods (40%), we have reached resilience. In this way, with the start of vaccination along with tracking the changes in consumer behavior, we reached the correct forecast and redundancy, then by applying 40% discounts and 40% increasing attention to the safety of unnecessary perishable foods, blockchain, and using robotics (40%), the response speed and visibility increased and we reached flexibility. In addition, the use of supporting suppliers led to the sharing of resources and risk and increased cooperation. In general, the behavior of the agent, considering the spread of Coronavirus (100%), at the first reason a sharp decline in consumer purchases for unnecessary foods, and then by utilizing various scenarios (25% vaccination (minimum)), blockchain, use of robotics (40%), discount (30%) and attention to the safety of unnecessary perishable foods (40%) we passed the crisis and reached the resilience of the supply chain of unnecessary perishable foods. With the increase of resilience in the perishable food supply chain, the economic costs of the supply chain include the costs of storing unnecessary perishable raw materials on the supplier side, and the final food products on the producer and distributor side, the social costs include the cost of labor loss (death due to covid-19) and the costs of hiring new labor and environmental costs, including the costs of recycling and disposal and the waste of disinfectants significantly reduced. In addition, we have achieved relative stability in the amount of environmental pollution by combining different strategies for the resilience of the unnecessary perishable food supply chain and increasing the demand for unnecessary food. Also, among different scenarios, discounting and robotics compared to awareness of food safety have had the greatest impact on increasing demand and subsequently on the resilience of the unnecessary perishable food supply chain under various disturbances.

4.2. Sensitivity analysis

In this section, it is required to compare which reference parameter the agent-based model is sensitive to and shows a meaningful reaction to its increase and decrease. In this manuscript, the partial scale method is used to elucidate the agent-based model sensitivity. This procedure tests the impact of each parameter not together by preserving constant the other agents on the objective function value. In this section of the numerical outcomes, the influence of the significant parameter, i.e., the possibility of each scenario (increase and decrease demand) is analyzed. We can review the changes in the agent-based model by changing its parameters. For example, we perform a sensitivity analysis of the tendency to purchase unnecessary perishable foods (demand) based on changes in the discount variable. We examine the impact of the discount variable by considering its minimum and maximum values. Figure 5 shows the tendency to purchase unnecessary perishable foods for the minimum/ maximum discount as a blue line. Also, the red line indicates a linear forecast. This allows us to observe the sensitivity of purchase intention to changes in the discount variable.

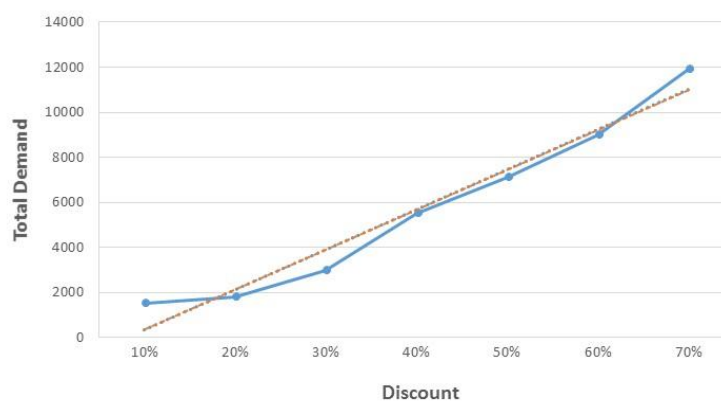


Figure 5. Sensitivity Analysis (discount)

Figure 6 shows a sensitivity analysis of the tendency to purchase unnecessary perishable foods (demand) based on changes in the awareness of food safety variable. We examine the impact of the awareness of food safety variable by considering its minimum and maximum values. Figure 5 shows the tendency to purchase unnecessary perishable food (demand) for the minimum/ maximum awareness of food safety as a blue line. This allows us to observe the sensitivity of purchase intention to changes in the awareness of food safety variable.

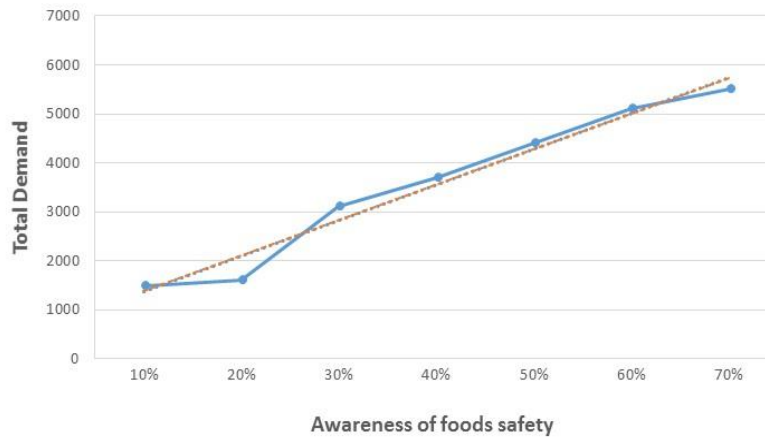


Figure 6. Sensitivity Analysis (awareness of food safety)

Figure 7 shows a sensitivity analysis of the tendency to purchase unnecessary perishable foods (demand) based on changes in the robotics variable. We examine the impact of the robotics variable by considering its minimum and maximum values. Figure 7 shows the tendency to purchase unnecessary perishable foods (demand) for the minimum/ maximum robotics as a blue line. This allows us to observe the sensitivity of purchase intention to changes in the robotics variable.

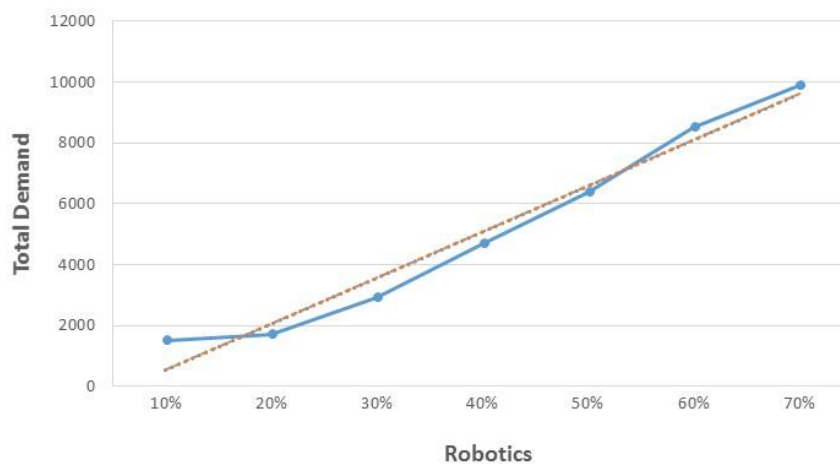


Figure 7. Sensitivity Analysis (robotics)

The results of the sensitivity analysis show that the two parameters of discount and robotics have the greatest impact on the desire to buy unnecessary perishable food (demand for perishable food) compared to other parameters (awareness of food safety).

5. Management Insight

The new challenge for business managers is to model and simulate an efficient and effective perishable foods supply chain network that is resilient enough to deal with different disruptions. Therefore, this research aims to model a resilient supply chain for unnecessary perishable foods using an agent-based simulation to deal with future disruptions. In this part, we contribute management insights based on the analysis.

- Modeling and simulation results indicate that the simultaneous use of a combination of different scenarios, such as consumer behavior tracking, discount, awareness of product safety, robotics, the use of blockchain among the levels of distributors and retailers, and the activation of several supporting suppliers, leads to a resilience supply chain of unnecessary perishable foods under different disruptions. Therefore, the vital of merging and interacting with different resilience scenarios during various disorders has been revealed more. Resilience scenarios should be regarded in an allied framework to profit from the synergistic impacts between them and gain the most suitable outcome. Therefore, the new necessity of managers working in unnecessary perishable food industries is modeling and simulation to investigate different scenarios for the resilience of the unnecessary perishable food supply chain. To make an unnecessary perishable food supply chain resilient under various disturbances, it is critical to expand and enforce an exhaustive strategic plan that includes all aspects of preparedness, response, and recovery. An exhaustive strategic plan is essential not only to respond to and recover from the recent predicament, but also to suitably prepare for the next disruption. Therefore, addressing different scenarios in all three dimensions of preparation, response, and recovery in an exhaustive strategic plan can more effectively contribute to the resilience of the unnecessary perishable food supply chain. Considering that perishable foods may not be stored for a long time and may spoil during the process in the supply chain. Therefore, executives should have suitable planning to motivate buyers to buy and consume unnecessary perishable foods, including informing buyers about the use of automation in the entire production process such as robotics (assuring the consumer that there is minimal human intervention in the production process), apply various discounts on perishable foods approaching the expiration date, provide advertisements on social networks to promote awareness of the safety of perishable foods, etc. The impact of various disruptions in the supply chain of unnecessary perishable foods leads to the lack of correct forecasting in the amount of demand and distribution and subsequently irreparable damages such as loss of food. Hence, by using blockchain technology, managers will be able to accurately and correctly predict the amount of demand and distribution, especially at the level of distributors and retailers, and prevent unnecessary waste of perishable food. Therefore, it is very necessary to use innovative technologies such as blockchain for the resilience of the supply chain of unnecessary perishable foods.

6. Conclusion

Statistical indicators denote that Coronavirus disease has damaged the Gross Domestic Product of all developed and developing countries. Iran is not an exception. These issues prompted researchers around the world, including Iran, to study more carefully the specific troubles in the supply chain of unnecessary perishable foods caused by the COVID-19 pandemic and develop resilience proposed action. Considering that after receiving the foods by the customer, it is always possible to return the foods to retailers for reasons such as the presence of a defect in the received foods or the expiration date of the foods. In the supply chain of unnecessary perishable foods, due to the short life cycle of the products, we are faced with a significant volume of expired foods in return foods collection centers, which makes managing the chain, burial, and recycling of foods challenging. During specific disruptions such as COVID-19, due to the sharp decrease in demand for unnecessary perishable foods, the volume of expired foods in return foods collection centers has increased, and chain management, landfilling, and recycling have become more challenging than before COVID-19. Hence, the principal goal of this manuscript is to design a resilient supply chain model for unnecessary perishable foods in the event of particular disruptions. For this purpose, the agents involved in different disruptions in the supply chain of unnecessary perishable foods include 1) suppliers, 2) producers, 3) warehouses, 4) distributors, 5) retailers, 6) consumers, 7) collection centers, 8) recycling, and 9) waste disposal. In addition to the items mentioned above, as can be seen from the review of the theoretical literature and the opinions of the research experts, 7 types of disorders generated by the outbreak of Coronavirus were identified in the field of the resilience of the perishable foods supply chain. These 7 types of disorders contain 1) fluctuations in buyer's behavior, 2) buyer's demand fluctuations, 3) goods production fluctuations, 4) supply fluctuations, 5) information flow fluctuations, 6) transportation fluctuations, and 7) financial fluctuations. In previous inquiries, only a few specific disruptions in the perishable foods supply chain have been examined. For instance, Ali et al., (2023) and Mishra et al., (2022) examined demand-side disruptions for the resilient supply chain of perishable foods. In addition, resilience strategies have been considered to reduce the effects of each disruption. For example, discount (30%) and product safety awareness (40%) strategies have been used to reduce demand fluctuations. Blockchain strategy (40%) has been used to decrease fluctuations in information, transportation, and finances. Robotics strategy (40%) has been utilized to decline production fluctuations. Also, among the diverse proposed actions, the discount has taken the most important role in the resilience of the supply chain of unnecessary perishable foods under certain interruptions. In previous studies, only one or several resilience strategies have been inquired. For instance, Sharma et al. (2022), and Kazancoglu et al. (2023) resilience strategy such as blockchain have been examined for perishable foods. Therefore, this research is the first effort to control all specific troubles and appraise all resilience proposed actions with each other for unnecessary perishable foods.

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