Supply chain modeling with system dynamics approach (Case study of Firooz Health Products Company)

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Abstract
Considering the application of system dynamics in supply chain management, this study aims at dynamic supply chain modeling in Firooz Health Products Company. This study used Vensim software to develop and validate supply chain modeling. In this regard, first identifies the components and variables of the chain based on the existing literature and then presents the dynamic hypothesis and after the causal loops and rate-state diagrams, tests the model based on the system dynamics method. Finally, the accuracy of the model is tested and policies to reduce lost sales, reduce inventory and receive accurate information to improve model indicators are presented. Based on the results, with a slight change in the logic of deciding the time of issuing orders from the distribution center to the production plant and knowing the inventory of raw materials at that time, the amount of reliability reserve, central warehouse inventory and distribution center warehouse inventory can overcome this problem. Can be a reason to increase the reactivity of the chain.

Keywords: supply chain, system dynamics, Firooz Health Products Company

Introduction

Supply chain management has developed greatly in the second half of the last century and has continued to do so in the present century. Development and adaptation of production and inventory control methods with the philosophy of timely production at the level of production lines and in order to properly control the flow of materials and products at the supply chain level in this area is one of the areas that has received much attention. Competition based on supply chain (SC) has become (Mohaqer et al., 2016). A supply chain includes all facilities (facilities), tasks and activities that continue in the production and delivery of a product or service, from suppliers to customers and includes supply and demand management and coordination, supply of materials, product production, warehousing, inventory control And the product is distributed to the customer. According to the definition of Supply Chain Management Professionals Association (CSCMP), supply chain is a flow of materials and information in logistics processes that exist from the stage of obtaining raw materials to the delivery of the final product to end customers (CSCMP, 2010). In a supply chain, decisions about inventory levels and how to control them affect each element of the chain, and this effect manifests itself in increased quality or reduced cost. Given this, decision-making about inventory in a supply chain can be considered as one of the most important supply chain management decisions (Strader, et al, 1998). Perhaps it can be said that the biggest problem of production and service organizations, after managing customer relations, is the proper management of the supply chain and the supply of production and service needs. The belief that supply chain management can make companies more accountable to customers and therefore more profitable, has led managers to place more emphasis on improving the supply chain process (Omidian et al., 2020).

The supply chain consists of different components and parts. The primary purpose of a supply chain is to meet customer needs through a process that creates a profit chain. Hence, the purpose of supply chain management is to maximize the profitability of the entire chain and maximize customer satisfaction (SBG, 2013). Because customer demand for different goods and materials can not be accurately predicted at all times. Therefore, if the supply chain divisions do not keep enough goods in their warehouses, there is a possibility of losing the customer and the possibility of complications due to lack of inventory. On the other hand, with all the benefits that inventories and their maintenance have, if not properly analyzed and analyzed, it will lead to chain losses. In other words, the ransom paid by the chain for customer satisfaction may come at the cost of destroying the chain. The issue of coordination, integration and prevention of adverse effects of supply chain inconsistency is one of the important issues in supply chains (Javadian et al., 2012), which in this study is used from the perspective of system dynamics (SD) approach to modeling.
Increasing research and interest of researchers and industrial managers in the field of supply chain has made it necessary to study the behavior of supply chain network systems. Therefore, the purpose of this study is supply chain

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modeling with a system dynamics approach in Firooz Health Products Company.

Theoretical Foundations

In mathematics, a dynamical system is a system in which a function describes the time dependence of a point in an ambient space. Examples include the mathematical models that describe the swinging of a clock pendulum, the flow of water in a pipe, and the number of fish each springtime in a lake. The most general definition unifies several concepts in mathematics such as ordinary differential equations and ergodic theory by allowing different choices of the space and how time is measured. Time can be measured by integers, by real or complex numbers or can be a more general algebraic object, losing the memory of its physical origin, and the space may be a manifold or simply a set, without the need of a smooth space-time structure defined on it.

At any given time, a dynamical system has a state representing a point in an appropriate state space. This state is often given by a tuple of real numbers or by a vector in a geometrical manifold. The evolution rule of the dynamical system is a function that describes what future states follow from the current state. Often the function is deterministic, that is, for a given time interval only one future state follows from the current state (*Strogatz, 2001*). However, some systems are stochastic, in that random events also affect the evolution of the state variables.

In physics, a dynamical system is described as a "particle or ensemble of particles whose state varies over time and thus obeys differential equations involving time derivatives".("Nature", 2001). In order to make a prediction about the system's future behavior, an analytical solution of such equations or their integration over time through computer simulation is realized.

The study of dynamical systems is the focus of dynamical systems theory, which has applications to a wide variety of fields such as mathematics, physics (Gintautas et al. 2008), biology,(*Jackson, T.; Radunskaya, 2015),* chemistry, engineering (*Kreyszig, 2011*) economics (Gandolfo, Giancarlo*, 2009)* history, and medicine. Dynamical systems are a fundamental part of chaos theory, logistic map dynamics, bifurcation theory, the self-assembly and self-organization processes, and the edge of chaos concept.

In the most general sense, (*Giunti and Mazzola, 2012, Mazzola and Giunti, 2012)* a dynamical system is a tuple (T, X, Φ) where T is a monoid, written additively, X is a non-empty set and Φ is a function

$$\Phi : U \subseteq (T \times X) \to X$$

with

$\mathrm{proj}_2(U) = X$ (where proj_2 is the 2nd projection map)

and for any x in X:

$$\Phi(0, x) = x$$
$$\Phi(t_2, \Phi(t_1, x)) = \Phi(t_2 + t_1, x),$$

for t_1, $t_2 + \in I(x)$ and $t_2 \in I(\Phi(t1, x))$

where we have defined the set I(x):={t ∈ T: (t,x) ∈ U} for any x in X.

In particular, in the case that U=T × X} we have for every x in X that I(x) = T and thus that Φ defines a monoid action of T on X.

The function Φ(t,x) is called the evolution function of the dynamical system: it associates to every point x in the set X a unique image, depending on the variable t, called the evolution parameter. X is called phase space or state space, while the variable x represents an initial state of the system.

We often write

$$\Phi_x(t) \equiv \Phi(t, x)$$
$$\Phi^t(x) \equiv \Phi(t, x)$$

if we take one of the variables as constant.

$$\Phi_x : I(x) \to X$$

is called the flow through x and its graph trajectory through x. The set

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$$\gamma_x \equiv \{\Phi(t,x) : t \in I(x)\}$$

is called the orbit through x. Note that the orbit through x is the image of the flow through x. A subset S of the state space X is called Φ-invariant if for all x in S and all t in T

$$\Phi(t,x) \in S.$$

Thus, in particular, if S is Φ-invariant, I(x)=T for all x in S. That is, the flow through x must be defined for all time for every element of S.
More commonly there are two classes of definitions for a dynamical system: one is motivated by ordinary differential equations and is geometrical in flavor; and the other is motivated by ergodic theory and is measure theoretical in flavor.

Geometrical definition
In the geometrical definition, a dynamical system is the tuple (T, M, f). T is the domain for time - there are many choices, usually the reals or the integers, possibly restricted to be non-negative. M is a manifold, i.e. locally a Banach space or Euclidean space, or in the discrete case a graph. f is an evolution rule $t \rightarrow f^t$ (with $t \in T$) such that f^t is a diffeomorphism of the manifold to itself. So, f is a

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"smooth" mapping of the time-domain T into the space of diffeomorphisms of the manifold to itself. In other terms, f(t) is a diffeomorphism, for every time t in the domain T .

Real dynamical system

A real dynamical system, real-time dynamical system, continuous time dynamical system, or flow is a tuple (T, M, Φ) with T an open interval in the real numbers R, M a manifold locally diffeomorphic to a Banach space, and Φ a continuous function. If Φ is continuously differentiable we say the system is a differentiable dynamical system. If the manifold M is locally diffeomorphic to Rn, the dynamical system is finite-dimensional; if not, the dynamical system is infinite-dimensional. Note that this does not assume a symplectic structure. When T is taken to be the reals, the dynamical system is called global or a flow; and if T is restricted to the non-negative reals, then the dynamical system is a semi- flow.

Discrete dynamical system

A discrete dynamical system, discrete-time dynamical system is a tuple (T, M, Φ), where M is a manifold locally diffeomorphic to a Banach space, and Φ is a function. When T is taken to be the integers, it is a cascade or a map. If T is restricted to the non-negative integers we call the system a semi-cascade (Galor, 2010).

Cellular automaton

A cellular automaton is a tuple (T, M, Φ), with T a lattice such as the integers or a higher- dimensional integer grid, M is a set of functions from an integer lattice (again, with one or more dimensions) to a finite set, and Φ a (locally defined) evolution function. As such cellular automata are dynamical systems. The lattice in M represents the "space" lattice, while the one in T represents the "time" lattice.

Multidimensional generalization

Dynamical systems are usually defined over a single independent variable, thought of as time. A more general class of systems are defined over multiple independent variables and are therefore called multidimensional systems. Such systems are useful for modeling, for example, image processing.

Compactification of a dynamical system

Given a global dynamical system (R, X, Φ) on a locally compact and Hausdorff topological space X, it is often useful to study the continuous extension Φ* of Φ to the one-point compactification X* of
X. Although we lose the differential structure of the original system we can now use compactness arguments to analyze the new system (R, X*, Φ*).
In compact dynamical systems the limit set of any orbit is non-empty, compact and simply connected.

Measure theoretical definition

Main article: Measure-preserving dynamical system
A dynamical system may be defined formally as a measure-preserving transformation of a measure space, the triplet (T, (X, Σ, μ), Φ). Here, T is a monoid (usually the non-negative integers), X is a set, and (X, Σ, μ) is a probability space, meaning that Σ is a sigma-algebra on X and μ is a finite measure on (X, Σ). A map Φ: X → X is said to be Σ-measurable if and only if, for every σ in Σ, one has
$\Phi^{-1}\sigma \in \Sigma$. A map Φ is said to preserve the measure if and only if, for every σ in Σ, one has
$\mu(\Phi^{-1}\sigma) = \mu(\sigma)$. Combining the above, a map Φ is said to be a measure-preserving transformation of X , if it is a map from X to itself, it is Σ-measurable, and is measure-preserving. The triplet (T, (X, Σ, μ), Φ), for such a Φ, is then defined to be a dynamical system.
The map Φ embodies the time evolution of the dynamical system. Thus, for discrete dynamical systems the iterates $\Phi^n = \Phi \circ \Phi \circ \ldots \circ \Phi$ for every integer n are studied. For continuous dynamical systems, the map Φ is understood to be a finite time evolution map and the construction is more complicated.

Construction of dynamical systems

The concept of evolution in time is central to the theory of dynamical systems as seen in the previous sections: the basic reason for this fact is that the starting motivation of the theory was the study of time behavior of classical mechanical systems. But a system of ordinary differential equations must be solved before it becomes a dynamic system. For example consider an initial value problem such as the following:

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$$\dot{\boldsymbol{x}} = \boldsymbol{v}(t, \boldsymbol{x})$$
$$\boldsymbol{x}|_{t=0} = \boldsymbol{x}_0$$

where
x represents the velocity of the material point X M is a finite dimensional manifold
v: T × M → TM is a vector field in R^n or C^n and represents the change of velocity induced by the known forces acting on the given material point in the phase space M. The change is not a vector in the phase space M, but is instead in the tangent space TM.
There is no need for higher order derivatives in the equation, nor for the parameter t in v(t,x), because these can be eliminated by considering systems of higher dimensions.
Depending on the properties of this vector field, the mechanical system is called autonomous, when v(t, x) = v(x)
homogeneous when v(t, 0) = 0 for all t
The solution can be found using standard ODE techniques and is denoted as the evolution function already introduced above

$$\boldsymbol{x}(t) = \Phi(t, \boldsymbol{x}_0)$$

The dynamical system is then (T, M, Φ).
Some formal manipulation of the system of differential equations shown above gives a more general form of equations a dynamical system must satisfy

$$\dot{\boldsymbol{x}} - \boldsymbol{v}(t, \boldsymbol{x}) = 0 \qquad \Leftrightarrow \qquad \mathfrak{G}\left(t, \Phi(t, \boldsymbol{x}_0)\right) = 0$$

where $\mathfrak{G} : (T \times M)^M \to \mathbf{C}$ is a functional from the set of evolution functions to the field of the complex numbers.
This equation is useful when modeling mechanical systems with complicated constraints.
Many of the concepts in dynamical systems can be extended to infinite-dimensional manifolds— those that are locally Banach spaces—in which case the differential equations are partial differential equations (Mehregan et al, 2010).

background research

Javadian et al. (2012) in a study identified factors affecting supply chain performance and its improvement using the dynamic system method. In this study, the main factors affecting the behavior of the whole system and the relationships between them are well known and three policies have been proposed and implemented according to the known indicators of supply chain performance evaluation.
These policies include reducing lost sales, reducing inventory, and receiving accurate information, the implementation of which has improved indicators. The result of this research is to enable us to predict the results before any changes in variables, relationships or chain structure, which is important given the complexity of the supply chain.
Azar et al. (2013) used the dynamics approach to study the interaction system between the industry chain and the university and based on different scenarios, explained the relationship between the two in the light of the Fifth Development Plan. Findings show that paying attention to time delays, reinforcing and balancing causal loops in the axes of quality, population and financial resources, to a large extent is effective in the effectiveness and coherence of the developed policies.
Faghih et al. (2014) in their study entitled Mathematical modeling of Iranian fixed communication services supply chain using the concept of dynamic systems, have used the existing and documented information of the Telecommunication Company from 2005 to 2012 and the results of simulation of system dynamics models until 1404. The modeling results show that the research system is controllable and observable; That is, system inputs control system state variables, and each state variable affects some of the system outputs and is stable according to the system simulation data.
Mohaqer et al. (2016) studied the dynamics modeling in the supply chain of a new product based on the system dynamics approach. In this study, the effect of variables related to the amount and uncertainty of demand and also the uncertainty of supply chain partners on the performance of the supply chain in a supply chain of two-level medical equipment production has been investigated. To analyze the behavior of the system in relation to changing uncertainty variables, system dynamics have been used, which is one of the powerful tools for analyzing and understanding the behavior of operations in supply chains. The results show that increasing the amount of demand, demand uncertainty, uncertainty of the production system and supply capacity have a great effect on intensifying the effect of leather whipping and reducing the level of customer demand satisfaction throughout the supply chain.

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Emami et al. (2019) in a study that was conducted to evaluate the performance of the dairy supply chain in rural areas of Kermanshah, show that the variables of information flow and coordination between network members, marketing and sales, customer satisfaction and transportation are in good condition. Enjoy. According to the results of simultaneous (simultaneous) multiple regression analysis and F test, the variables of information flow and coordination, marketing and sales, customer satisfaction and transportation have a significant effect on supply chain performance, while the two variables of cost and flexibility are favorable. They were not.

Omidian et al. (2016) in a study called supply chain optimization modeling of the country's electricity industry using a combined method and Novo software developed a basic model of factors affecting supply chain optimization. The results show that the relationships between variables and the type of variables can lead to a better understanding of the issue and appropriate decisions in the supply chain optimization problem.

Rodriguez et al (2021) In his study entitled System Dynamics Modeling in Additive Manufacturing Supply Chain Management, proposed a dynamic hypothesis that defines the following issue: what is the impact of the AM characteristics and processes in the SC? The model was represented through a causal diagram in thirteen variables related to the SC, organized in two feedback cycles and a data flow diagram, based mainly on the three-essential links of the SC and the order display traceability: supplier–focal manufacturer–distribution Network. Once proposed, the model was validated through the evaluation of extreme conditions and sensitivity analysis. As a result, the dynamic behavior of the variables that condition the chain management was analyzed, evidencing reduction times in production, especially in products that require greater complexity and detail, as well as reductions in inventories and the amount of raw material due to production and storing practices from AM. This model is the starting point for alternative supply chain scenarios through structural operating policies and operating policies in terms of process management.

Jamaludin et al (2021)) In his study entitled A system dynamics approach for analyzing supply chain industry: Evidence from rice industry, analyze the simulation of the rice industry supply chain system policy; and recommend rice industry policies which provide incentives for all rice industry supply chain actors.

The results show that the rice industry supply chain system model is a closed cycle consisting of material flow feedback in the form of grain, rice, money and information flow in the form of demand that occurs in the interaction of actors from farmers, grain traders, rice milling units (RMU), rice traders in production centers to rice traders in urban wholesale markets in Bandung and Jakarta. Every businessman in the rice industry has the same goal, which is to maximize the profits. The impacts of this partial policies are farmers, collectors, rice traders and rice mills gain unstable profits and the benefits received are lower than before the production strategy and policy were implemented.

The focus of study's Lagarda-Leyva (2021), is centered on dry, long shelf-life products used in the packaging process of a marketing company in the southern part of Sonora, México. The completion of this project met the objective of developing a graphical user interface that would allow for analyzing the packaging process of shelf products in different scenarios, considering the demand and decision-making based on quantitative data. Thus, the purpose of solving the problem detected was achieved by finding the technological solution and observing the use of the packaging process in the function of the demand. With these detected actions, the company under study was able to understand how the most critical variables of the production link behave and close the gap in the lack of information for decision-making, which is based on empirical data, improving the development of the company, and from the perspective of previous empirical studies reviewed in this research. Therefore, the scientific contribution of this study, from the perspective of the dynamic systems theory, is based on the use of mathematics, systemic thought, and general system theory. The purpose is to model, mathematically, and in cause–effect relationships, complex productive systems of non- linear behavior through dynamic simulation that allows for having information on future scenarios for decision-making based on endogenous and exogenous data and variables.

Abdullah et al (2019), In their paper, a system dynamics approach is used to simulate a three stages supply chain system experiencing supply disruption. The supply chain system consists of single supplier, manufacturer and retailer. The model is developed suggesting backlogged and inventory as the primary performance measure. The model is tested under three conditions, which are normal condition, disruption condition and disruption with a mitigation strategy. The main findings from the study are lead time changes on the entire system directly impact the inventory of the entire stages in the system. Furthermore, the disruption occurence produces an adverse effect on supply chain performance for a period longer than the actual period of the disruption and likewise, influence system performance.

Sharma et al. (2017) in a study entitled Performance Indicators Related to Green Supply Chain Management in the Agricultural Industry, aimed to examine supply chain management related to performance indicators. Based on the results of internal environmental management, environmental design and legal pressure are variables that are known to affect the supply chain.

Methodology and model presentation

This study is of developmental-applied type in terms of research purpose. Also, considering that in this research, data

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related to a food packaging industry in Tehran in 1399 have been used to describe and decide on the existing conditions, in terms of data collection is descriptive. The information used in this study is related to one year of production, storage and sale of products related to Firooz Health Products Company, which has been collected and stored in the research department of this company.

Steps of conducting research

First, by examining the past behavior of variables in the study supply chain and receiving the opinion of experts and senior and middle managers of the organization, the factors affecting the chain are identified and categorized. Then, the behavior of each factor over a specified period of time is examined and presented in the form of reference charts. By examining information about the behavior of variables, logical relationships are extracted from how they affect each other, and after stating the dynamic hypothesis, the relevant cause-and-effect diagram is prepared. After reviewing and modifying the cause- and-effect diagram, the rate and mode model is prepared. Also, the time of completing the rate and state model, the completed mathematical formulas and the mathematical model are formed. The designed model is implemented and the behavior of the variables in the model is compared with their behavior in reality by known methods of system dynamics and the accuracy of the simulated model is ensured. After ensuring the ability of the model to simulate the actual behavior in the supply chain, according to the supply chain performance indicators, policies to improve these indicators are presented and the results are presented and evaluated while presenting how to apply changes in the model by implementing the new model. Placed.

Provide a model of system dynamics

In this research, the methodology presented by Sterman in the book Business Dynamics has been used. These steps are:

1. Define the problem of dynamics and its scope
2. Determine the variables and determine the relationship between them
3. Drawing causal diagrams
4. Model formulation in rate and mode diagrams
5. Model simulation
6. Model test
7. Suggest policies

The staggering costs of fluctuations in inventory are always one of the most important issues in the supply chain. Inventory maintenance costs when inventory is more than needed and costs due to shortage of goods when inventory is less than needed, has raised the issue of forecasting and controlling fluctuations as an important issue in the supply chain of Firooz Health Products Company. In Figure (1), to show the dynamic hypothesis, the total inventory of goods and the range of its changes in the central warehouse are shown to show the importance of the issue and the need to control the behavior of this variable. As it is known, the inventory in the central warehouse varies from less than 1000 tons to more than 2500 tons.

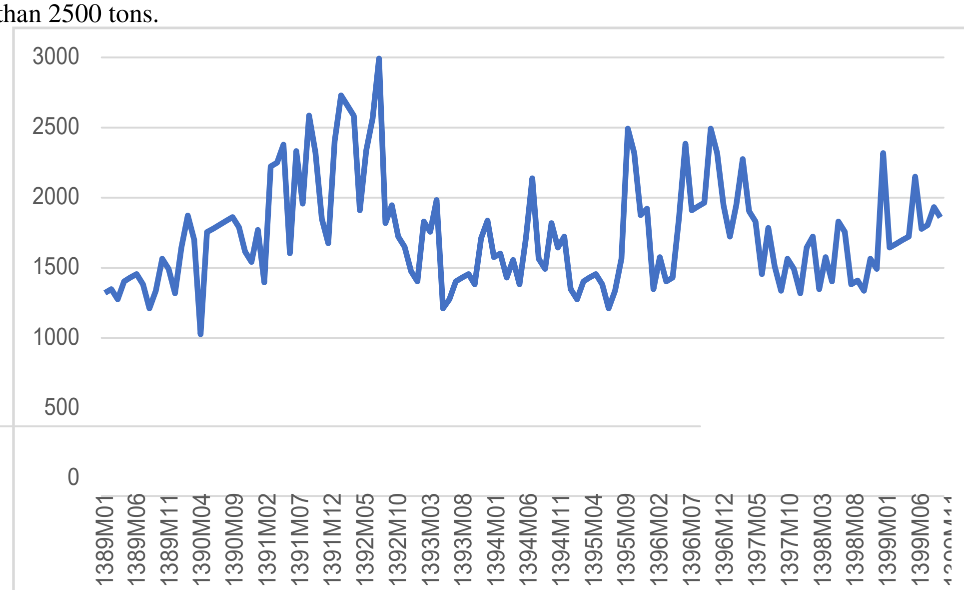

Figure 1: Fluctuations in inventory

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This unfavorable behavior of inventory in the central warehouse and its fluctuations occur for various reasons and different variables of the entire supply chain affect its behavior. Therefore, to solve the problem, it is necessary to identify these influential variables, extract their behavioral patterns and model how they affect each other and the volatility of warehouses.

Identifying the effective variables in the supply chain of Firooz Health Products Company

Firooz Health Group is one of the largest producers of child health products in Iran and the Middle East. In this study, a product of this company is studied as a product. Also, a supplier of the main material for the production of this product has been selected as a supplier of the level of a chain. Other variables identified in the supply chain based on the initial knowledge of the company, including seasonal market shock, sales rate, distribution center inventory, warehouse inventory, confidence in warehouse distribution centers, shipping volume, production rate, shipping time from central warehouse The warehouses of the centers are the amount of order for production, production capacity, time required for production, amount of order for purchase of materials and inventory of materials in the supplier warehouse. At this stage, based on the initial knowledge of the organization, the actual behavior of these variables is examined as a reference behavioral pattern and the dynamic hypothesis is proposed based on their behavior.

Presenting a dynamic hypothesis

The study of the behavior of the identified variables shows that the root of the behavior of the variables can be considered as the result of the behavior of the sales variable in the distribution centers. Of course, this is a two-way effect, and in these interactions and the resulting circles, the place of cause and effect is changing and shifting.

Cause and effect diagrams

The variables proposed in the dynamic hypothesis and the factors affecting their behavior are measured and according to the type of relationship between the variables and the feedback loops resulting from the relationship between the variables, a cause-and-effect diagram is designed step by step. Finally, only the final cause-and-effect model of the entire supply chain is presented in Figure (2).

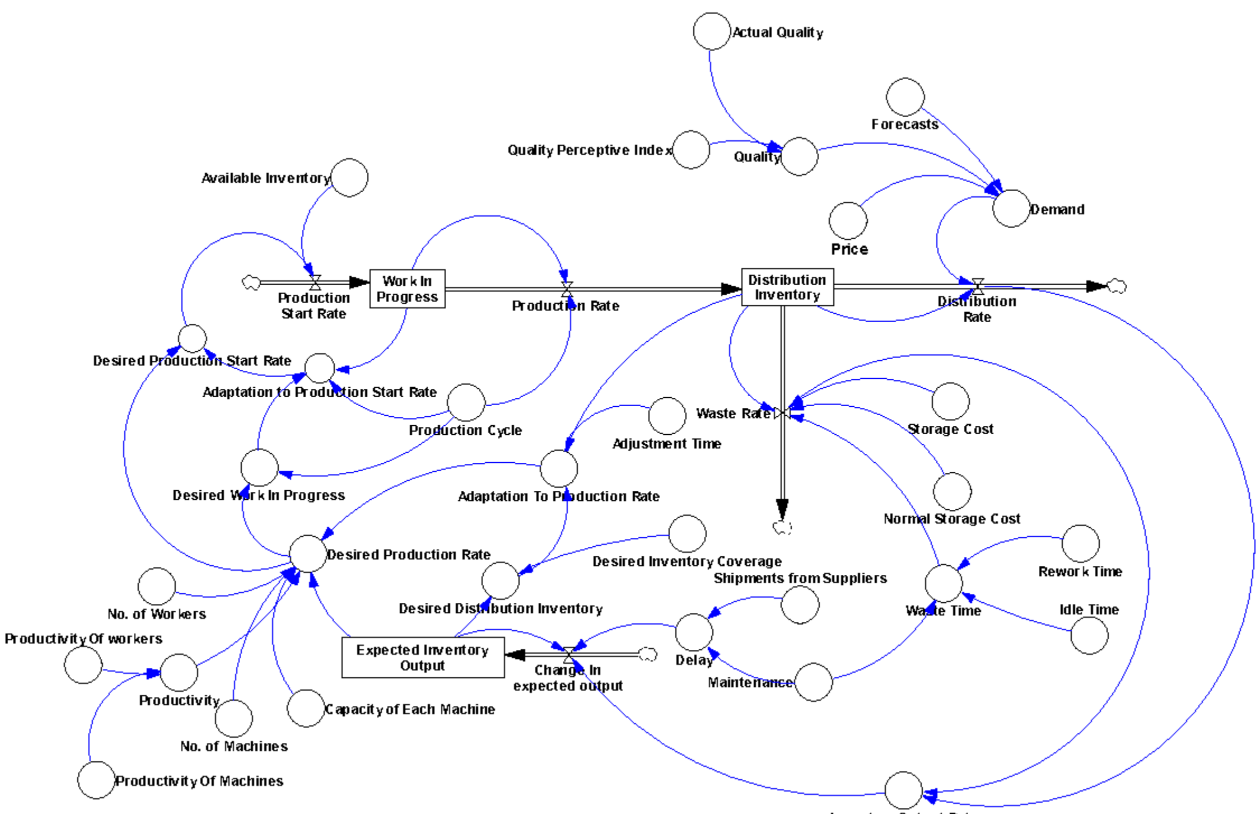

Figure 2 a: Cause and effect diagram of the supply chain

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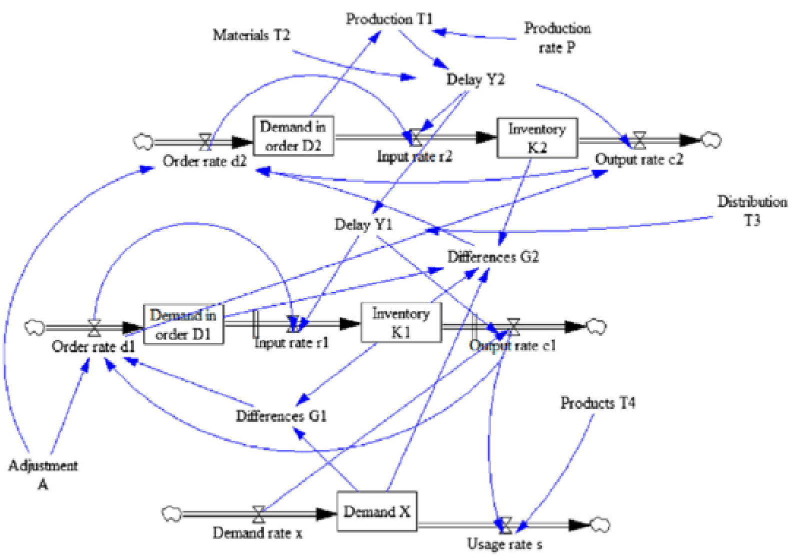

Figure No. b2: Cause and effect diagram of the health supply chain

Rate and mode chart (flow and inventory)

Figure (3) shows the cause and effect diagram and the rate and mode diagram.

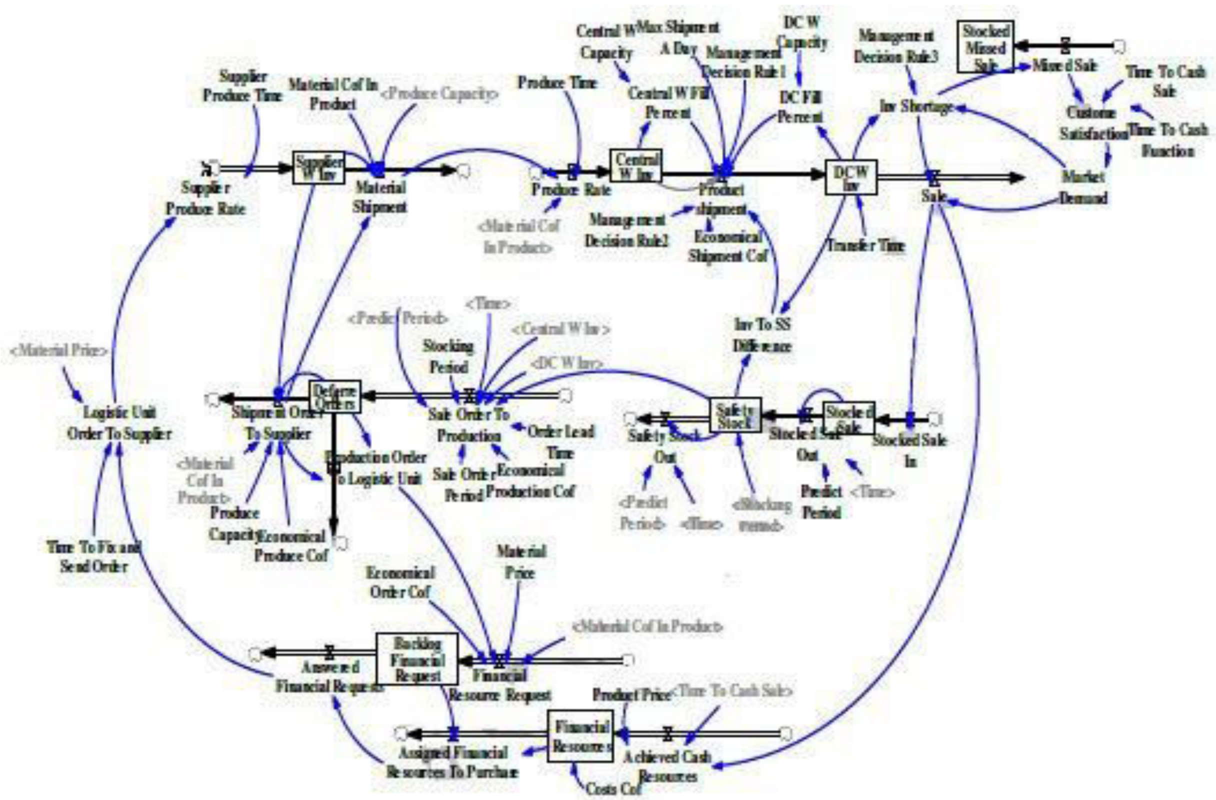

Figure 3: Flow chart and inventory

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Model testing and simulation

In this section, Vensim software is used for problem calculation and modeling and the model is simulated for the years 1389 to 1399. In order to test the validity of the model, test the adequacy of the model through the accuracy of endogenous and exogenous variables according to the set boundaries, check the conformity of the model with reality in the decision-making stages and harmonize with existing rules. And the materials have been performed and confirmed based on the assumptions as well as the dimensional test in order to determine the unit of variables and their coordination with reality.

Reproduction validation validation test

One of the most important and effective tests to check the validity of the model is the behavior reproduction test. This test examines whether the model can reproduce the behavior shown by the actual system. To perform this test, it is necessary to first obtain real data from previous periods and then compare the real data with the simulation results. The following equation is used for this purpose. This relationship has been used in some previous studies in the field of system dynamics (Hassanzadeh et al., 2012: 113).

$$R^2 = \left(\frac{\sum_{i=1}^{n}(S_i - S^-)(O_i - O^-)}{\sqrt{\sum_{i=1}^{n}(S_i - S^-)^2 \sum_{i=1}^{n}(O_i - O^-)^2}} \right)^2$$

Using this equation, the validity of the model will be equal to 95%, which is a very desirable value and indicates the validity of the model. See also Figure (4) for a comparison between real values. The simulated results also confirm this amount of validity.

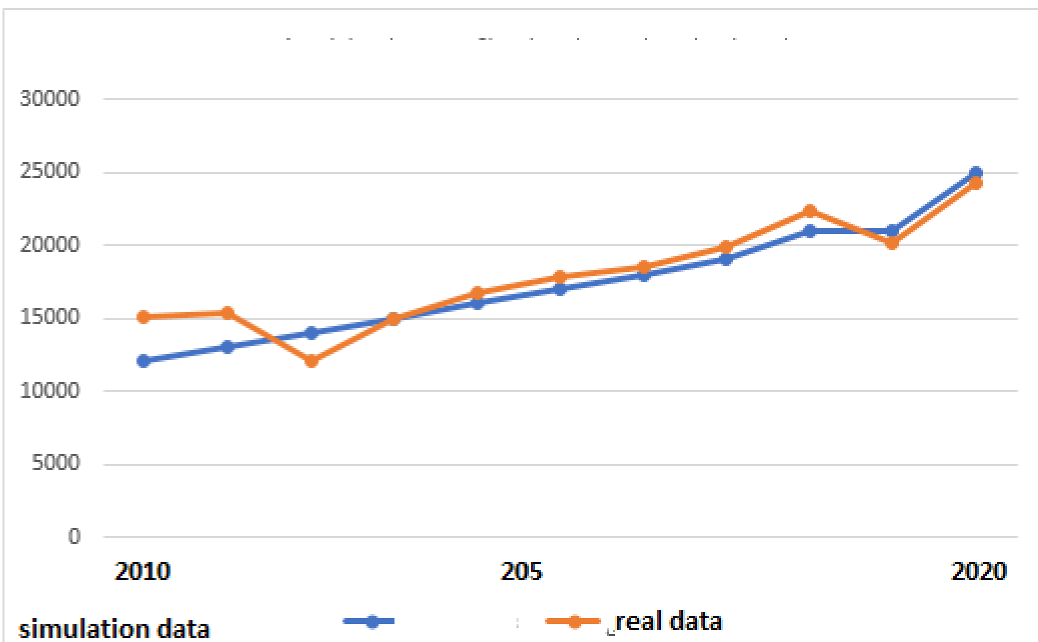

Figure (4): Comparison of real results and simulation data

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In a general evaluation of the results of the study of the behavior of variables, it can be said that the general shape of the graph and the obtained statistics have largely confirmed the reliability of the model due to the complexity of the system. In this case, this model can be used to analyze the sensitivity of variables. This model can also be used to provide policies to improve chain performance and observe their results in the system.

Scenario presentation

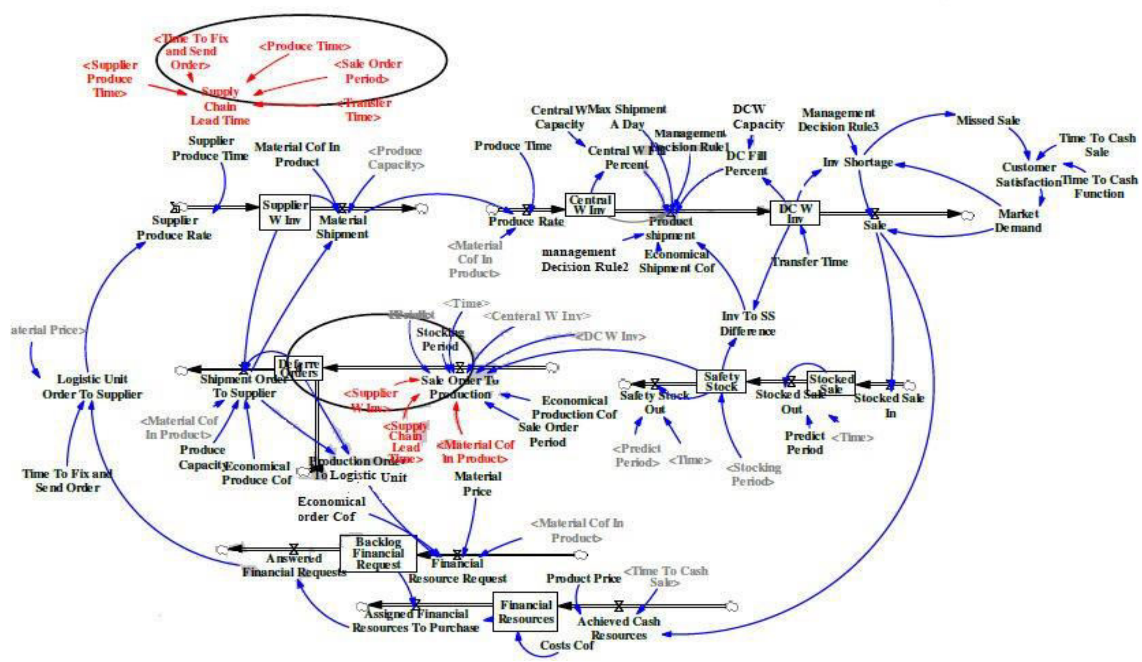
In order to use the defined indicators in evaluating supply chain performance, policies that are proposed to change the variables, change some relationships, delete some variables or add some variables to the model are presented, and by implementing them in the model, it is possible to see And evaluation of results is provided before implementation in the real world. This section refers to the policies presented in this area and describes a policy.

Scenario of reducing lost sales

By studying the sales situation and the lost sales variable, it was observed that a high rate has been converted into lost sales due to lack of inventory. After reviewing the model, it seems that the lack of information of different parts of the chain about the status of other units has caused this crisis. However, at the time of the action, all units performed their duties correctly and on time. But what has caused this problem is the lack of timely information. A closer look at the model revealed that the reason for this crisis was the lack of awareness of the distribution center about the initial inventory situation in the warehouse, which provided the time for announcing the order to the production plant.

Therefore, this problem can be overcome by slightly changing the logic of deciding when to place orders from the distribution center to the production plant and knowing the inventory of raw materials at that time, as well as defining a variable called chain forward time instead of forward order. Modifications to the model are applied in the figure below.

Figure (5): Changes made in the model after applying the scenario of reduced sales



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By making these changes according to the chart below, the lost sales will be almost completely eliminated (Figure 6).

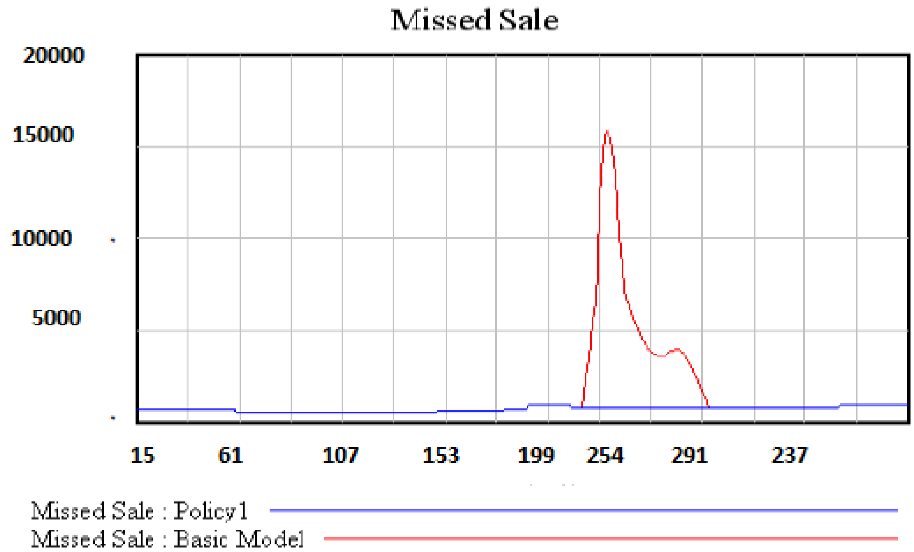

Figure (6): Comparison of lost sales charts before and after policy

Inventory reduction scenario

With the implementation of this policy, the amount of confidence reserve, central warehouse inventory and distribution center warehouse inventory was greatly reduced and lost sales did not increase except for a short period of time.

Scenario of receiving correct information

With the implementation of this policy, the confidence reserve curves, the central warehouse inventory and the distribution center inventory inventory were shifted to some extent, which indicates a faster and more accurate response to changes. Lost sales also fell.

Conclusion

In order to model the supply chain, this study has identified the effective variables in this field about Firooz Health Company and evaluated the relationships between them and how they affect the supply chain of this company. The simulated supply chain model is designed based on the system dynamics method using vensim software. Then, based on the available real data and the existence of sufficient information about the behavior of these variables, the simulated behaviors are compared with reality and the results are tested with possible methods. The high adaptation of the simulated model performance to the actual chain performance shows that the identified variables are to a large extent the main variables affecting the chain performance behavior. Accordingly, in order to improve the current situation, policies have been proposed and its effects on the system have been evaluated before implementation. Despite the uniqueness of the indicators of each supply chain, but some indicators that are considered as key indicators and are present in most studies, are divided into four groups in which one or two indicators are selected and calculated from each category. The performance of the simulated model before and after the implementation of policies is compared with the values of these indicators. The results are presented in Table 1 and show the improvement of the model in three parts: delivery performance, assets and inventories and costs. Also, although there is no change in the index of increasing responsiveness due to the fact that the chain advance time has not changed, but as mentioned in the analysis of policy one problem, the lost sales generated in the initial model by increasing information sharing and usage Since then, it has shrunk significantly during decision-making. In fact, after the implementation of policies, the shocks entered were well responded by the chain, which can be a reason to increase the reactivity of the chain. The applicability and practicality of the model of this study in the industrial space of the country is one of the strengths of this study that can play an effective role in preventing the consequences of wrong decisions in complex systems.

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Table No. (1): Key performance indicators of Firooz Company before and after the implementation of the proposed policy

The rate of the index after the implementation of the policy	The amount of the initial index	Index name	Index group name
3/81%	7/96%	Service level	Delivery function
9/4859	55/7645	Predictive accuracy	
1/96	1/96	Planning course time	Supply chain responsiveness
5/4%	4/3%	Inventory turnover	Assets and inventories
259%	580%	Maximum storage capacity required	Cost

Research proposals

It is suggested that in other studies in this field, suppliers and distributors increase in several vertical and horizontal levels, in which case, timely access to all items needed to produce the product and the need to coordinate orders with different forward times, as well as related issues. Proper delivery of goods between distribution centers and prevention of shortage of goods is discussed. In addition, it is suggested that economically effective parameters be included in the model.

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