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Research Article

Measurement of the Satisfaction Level of the Country's Pharmaceutical Industry with Suppliers of Raw Materials in This Industry Using System Dynamics

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Abstract

Background: The success of the supply chain can be summed up in the satisfaction level of business partners and customers, according to several diverse needs of each of the business partners in the studied supply chain, including the country's pharmaceutical industry and suppliers of raw materials.
Methods: This study has attempted to investigate satisfaction according to the views under possible scenarios to improve satisfaction. The model presented in this regard to realize the main objective of this study is based on the principles of system dynamics, and VENSIM DSS has been used for its design.
Results: according to the study results, it can be acknowledged that the satisfaction of each of the business partners with the supply chain is different from each other, and the best scenarios to improve the satisfaction include an improvement of 3% in inventory management and a reduction by 5% in rework and parallel work during the studied period.
Conclusions: Under this scenario, the satisfaction of business partners in this regard will improve during the studied period, or in other words, the satisfaction of the parties will move optimally.
Keywords: Supply Chain; Satisfaction; System Dynamics

1. Background

In such a situation, businesses should prepare to face continuous challenges like economic crises, exchange rates, price fluctuations, and production system limitations (1). Desiring the increasing importance and complexity of supply chain management for organizations in today's turbulent workplace, prediction and realization of the resilience capabilities of the supply chain is necessary to deal with or prevent disruptions in the organization's activities (2). Hence, if an industry's supply chain cannot perform its tasks correctly, its efficiency will reduce. This importance should be considered even more in difficult and critical situations.

The main objective of supply chain management is the balance between the efficiency and responsiveness of a chain, which is measured in relation to the customers of that chain. In this regard, predicting customer demand, on the one hand, and creating a balance between the activities done along the chain to meet customer demand, on the other hand, can help to balance the efficiency and responsiveness of the supply chain (3).

Every system in the real world is not immune to turbulence. A company's supply chain is not exempt from this, and the small and large turbulence occurring in each department provides the basis for a reduction in the proper supply chain performance (4). The beginning of the Covid-19 pandemic in late 2019 in China and its spread in other countries is an example of a crisis in the real sense, which has rarely been recorded in the history of such a phenomenon (5). With the outbreak of this epidemic, turbulence occurred in the supply chain of the world's pharmaceutical industry. More resilient supply chains can manage this crisis better. Accordingly, in the present study, an attempt has been made to present a dynamic model not only to investigate the current situation of the supply chain in the country's pharmaceutical industry but also to present scenarios to improve the resilience of the supply chain in the face of environmental turbulence. In this regard, it should be noted that the presentation of the supply chain model in the pharmaceutical industry using system dynamics is important from various aspects. First, its use causes considering the symbolic characteristics of the supply chain, such as non-linear relationships, delay, and feedback loop. Second, adopting this method will change the context of developing the supply chain system in this industry. It allows the above system to quickly respond to the changes caused by the market demand while keeping its stocks at the minimum optimum level.

1.1. Theoretical Principles

The supply chain is a network that includes suppliers of raw materials, production centers, distribution centers, wholesalers, retailers, and finally, the end customers of the products. Supply chain management is responsible for planning, implementing, and efficiently controlling the flow of raw materials, inventories in the process of manufacturing, finished products, and the flow of information related to them from the beginning to the point of consumption aimed at meeting the needs of customers (6). Supply chain management is a complex activity with a wide range of risks, including small risks, such as delay, and large risks, such as supply chain turbulence (7). In other words, supply chain management is a comprehensive philosophy for managing the flow of distribution canals from supplier to consumer and provides a means for the continuous exchange of information and improving the performance of organizations (8). Due to the ineffectiveness of traditional risk management methods, it is necessary to consider the supply chain's resilience.

In this field, resilience can be described as measuring the system's ability to absorb continuous and unexpected changes and maintain its vital functions (9). In other words, resilience can be defined as the adaptability and response of the supply chain to turbulence, improving and recovering in a timely and cost-effective manner and advancing towards the performance after the turbulence. In the ideal case, it is better than before the turbulence occurred (10).

1.2. Literature Review

In a study, Rahimian and Rajabzadeh Ghatari (11) measured the supply chain's resilience by the approach of complex adaptive systems in Iran's pharmaceutical industry. The study results showed the basis for analyzing resilience and selecting an effective strategy to reduce supply chain risk for managers in this industry.

Sedighpour et al. (1), in a study entitled "Design and Explanation of a Model for Resilient Supply Chain in Iran's Pharmaceutical Industry," concluded that pharmaceutical industry managers could gain the necessary resilience through capabilities and enablers while reducing the factors that make companies susceptible to turbulence.

The study results of Amin-Tahmasbi and Hami (12) entitled "Analysis of Resilience and Sustainability Criteria of Supply Chain in the Pharmaceutical Industry using Interpretive Structure Analysis" showed that factors such as learning, stakeholder management, the field of vision, organization, position in the market, economic power, internal and external pressure are powerful factors for the resilience of supply chain, which should be considered more than other factors.

In a study, Ashrafi-rizi and Kazempour (5) explained the crisis of coronavirus (COVID-19) based on the disinformation theory.

2. Methods

From the methodological point of view, this study is mixed exploratory. For this purpose, a comprehensive image that is the basis of the model has been presented first for modeling using system dynamics. Accordingly, the cause-effect models have been structured according to observations about the system's behavior and excited by accepted theories extracted from theoretical principles.

This study desired the subject and theoretical principles of the research and achieved the main objective of the research - to measure the satisfaction of the country's pharmaceutical industry with suppliers of raw materials using system dynamics - the trace of crisis factors affecting the satisfaction of the country's pharmaceutical industry with suppliers of raw materials has been investigated, which has been designed and analyzed using VENSIM DSS. The time horizon of this study is four years, from 2019 to 2023. In order to predict and simulate the system dynamics model consistent with this study's objective, data were collected from structured interviews conducted with experts who have worked in this field. Table 1 presents all the variables used in this study and the cases used in the simulated model.

Table 1. Variables Used in the System Model

No.	Variables
	… et al. (2006) and Mahmoodi et al. (2010)
1	Desired delivery rate
2	Component order rate
3	Components on order
4	Desired components on order
5	Adjustment for components on order
6	Scrap rate of damaged components
7	Scrap rate of components with manufacturing faults
8	Scrap rate of components made from defective materials
9	Supplier delivery delay
10	Desired production rate
11	Production rate
12	Minimum components preparation
13	Shipment rate
14	Lead time
15	Inventory management
16	Nominal production capacity
17	Actual production capacity
18	Finished product inventory
	Latin
	… (2000)
19	Schedule pressure
20	Level of complaint
21	Cost of services and resources
22	Level of satisfaction
23	Efficiency
24	Customer satisfaction with the quality of delivered products
25	Customer satisfaction with responding to requests
26	Customer satisfaction with delivery time
27	Human resources training
28	Advanced technologies in production
29	Rework and parallel work
30	Responding to an instant delivery request
31	Working capital
32	Profit/income
	Researcher
33	Supplier loyalty
34	Debts settlement
35	Timely payment

2.1. Definition of Key Variables and Causal Relationships of the Research

As a result of the theoretical principles, literature review, and factors affecting the satisfaction of the country's pharmaceutical industry with raw material suppliers, the variables presented in Table 1 were used. The relationship between extracted variables in system dynamics is first expressed in the framework of reinforcement and balance loops, and then the general state of the model is displayed based on causal relationships. This study's multiplicity of causal loops just described the main loops. In the presented models, loops marked R are called reinforcement loops, and loops marked B are called balance loops.

B1, shown in Figure 1, shows that the components on order will change consistently with the change in the desired delivery rate. This happens to cause a delay in delivery and the store of orders in this step. Accordingly, adjusting the components on order will increase (reduce). This change was made to reduce the schedule pressure. As a result, it can be expected that according to the limited capacity available in each sector, the finished goods inventory will reduce (increase). The reduction (increase) in production capacity will change the actual production capacity in this regard, providing the basis for increasing (reducing) the delay in delivery by the supplier for all received orders. Finally, the increase (reduction) in the delay in delivery from the supplier causes the expected delivery rate to change consistent with the change or increase (reduction). R1 has a trend similar to what was previously mentioned about B1, with the difference that the change in the order rate determines the desired delivery rate. The components and the lead time of the production process will change. In the above loop, it can be seen that the increase (reduction) in the delay in delivery from the supplier provides the basis for the increase (reduction) in the dissatisfaction of customers and, consequently, the reduction (increase) in the order rate of components. By reducing the schedule pressure by reducing the orders, the lead time of the production process will reduce (increase). It can be said that reducing (increasing) the lead time of the production process will reduce (increase) the desired delivery rate.

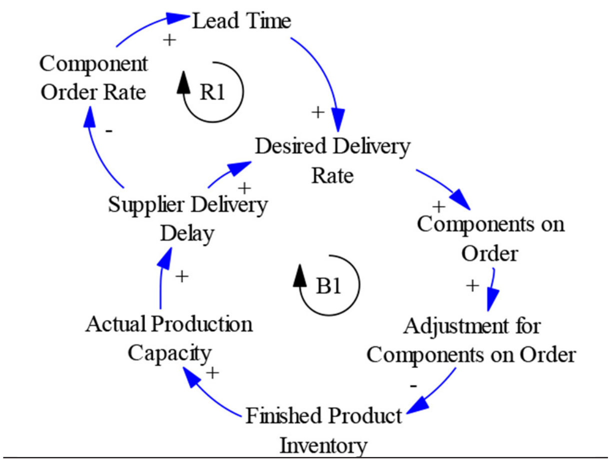


Figure 1. Balance ring and desired delivery rate booster (reference: study results)

B2, shown in Figure 2, emphasizes that if the desired delivery rate increases (reduces), then the component order rate will also reduce (increases) due to the dissatisfaction (satisfaction) of the customers. Hence, the number of orders reduces (increases), and as a result, the lead time of the production process also reduces (increases). It should be noted that substantiation of this importance provides the basis for reducing (increasing) the desired delivery rate for the supplier. However, the reinforcement loop R2 goes through a process similar to what happens in the balance loop B2 until it affects the order rate of the components. But as shown, this loop changes the desired delivery rate through a change in the adjustment of the components on order consistent with the order rate of the components, and then an inverse effect on the change in the lead time of the production process will change the desired delivery rate.

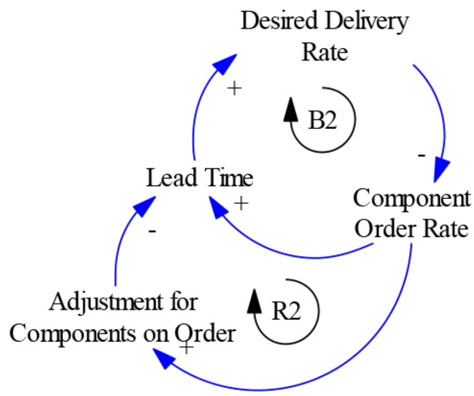


Figure 2. The balancing loop and time booster between the start and end of the production process (reference: study results)

R3, shown in Figure 3, confirms that an increase (reduction) in the level of legal complaints will increase (reduce) schedule pressure. Consequently, an increase (reduction) in schedule pressure will change the actual production capacity in the opposite direction of the change, providing the basis to increase (reduce) the delay in delivery from the supplier and, as a result, the customer's satisfaction with the delivery time of the products will be changed in the opposite direction of the change. Last but not least, the reduction (increase) in customer satisfaction at the time of product delivery will lead to an increase (reduction) in the level of legal complaints from the supplier.

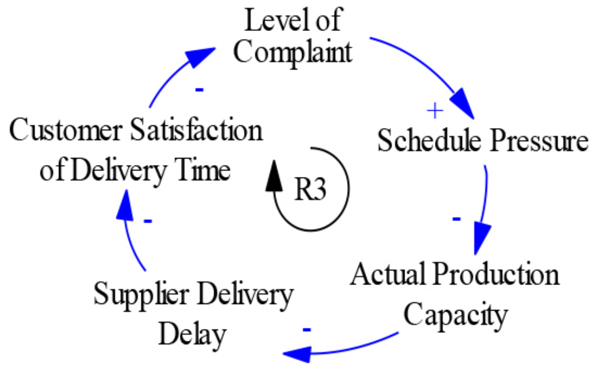


Figure 3. The reinforcing ring of the level of legal complaints-time pressure (reference: study results)

R4 shows that an increase (reduction) in the level of legal complaints will increase (reduce) the cost of resources and services. An increase (reduction) in the cost of resources and services will reduce (increase) the efficiency providing the basis to reduce (increase) the real production capacity. The change will reduce (increase) the delay in delivery from the supplier and consequently increase (reduce) schedule pressure. Finally, an increase (reduction) in schedule pressure will change the level of legal complaints consistent with the change (Figure 4).

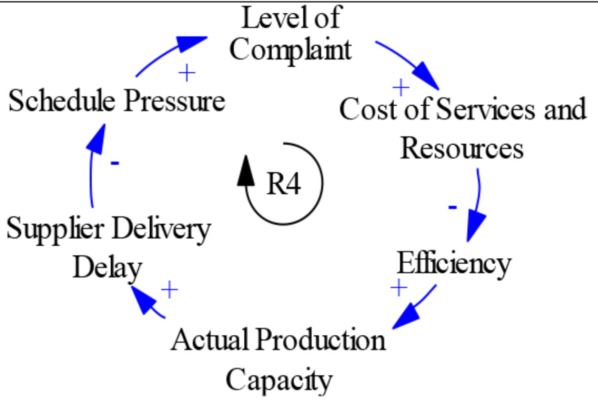


Figure 4. Reinforcement loop of the level of legal complaints - the cost of resources and services (reference: study results)

R5 shows that the increase (reduction) in actual production capacity will increase (reduce) the delay in delivery from the supplier. The delay will cause the supplier to reduce (increase) the order rate of components. Consequently, due to the reduction (increase) in orders and schedule pressure, the lead time of the production process will reduce (increase). This trend reduces (increases) the desired delivery rate and increases (reduces) the components on order. In this regard, adjusting the components on order will reduce (increase) by increasing (reducing) the components on order. Accordingly, it should be expected that the inventory of manufactured goods and, consequently, production capacity will increase (reduce).

The reinforcement loop shown in Figure 5 shows that the increase (reduction) in the cost of resources and services will reduce (increase) efficiency, and the actual production capacity will reduce (increase) in this regard. With the reduction (increase) in actual production capacity, the delay in delivery from the supplier should be expected to increase (reduce). First, this change reduces (increases) customer satisfaction from the time of product delivery and then increases (reduces) the level of legal complaints caused by this dissatisfaction (Figure 6).

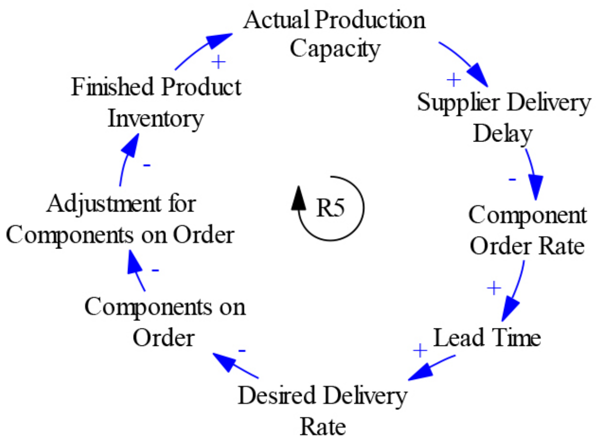


Figure 5. The loop that reinforces the cost of resources and services-productivity (reference: study results)

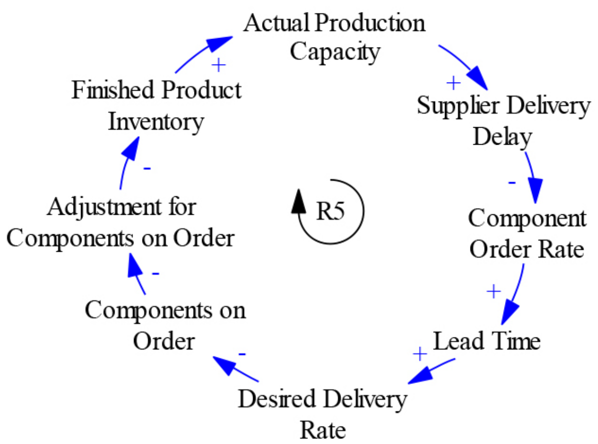


Figure 6. The actual production capacity amplifier loop (reference: study results)

After investigating the main loops of the research model, a causal diagram has been presented below in this section. It should be noted that this is shown in Figure 7.

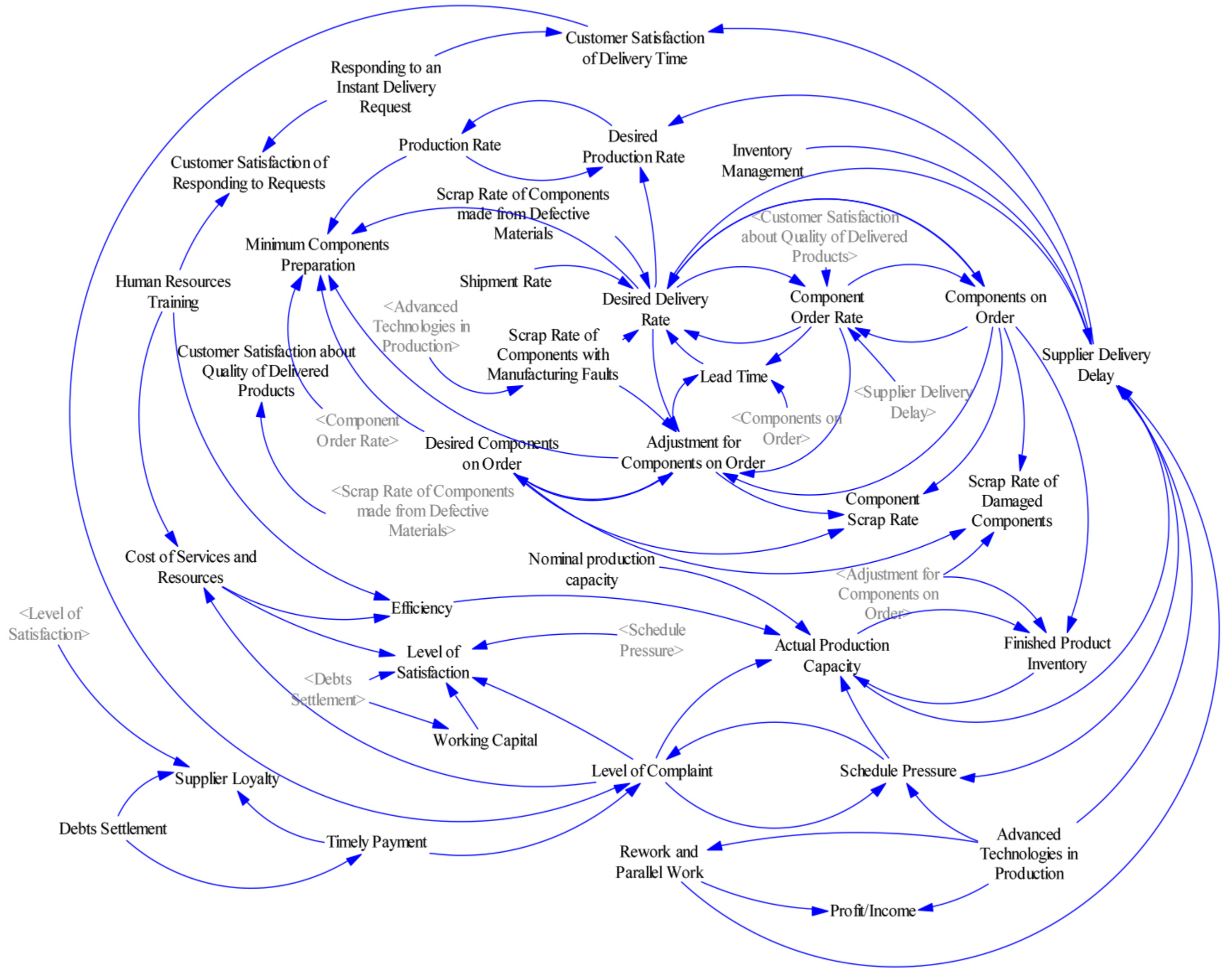


Figure 7. Diagram of cause and disability of research

3. Results

Tests to validate the results created from the model should be performed; the software does the initial step of which, and as a result, their explanation is omitted. In this section, other tests are described in detail.

3.1. Behavior Reproduction Test

This test compares the simulation results with the existing data based on a retrospective view to ensure the simulated model performance. Figures 1 and 2 show that the real information and the results from the variable simulation of the satisfaction of the country's pharmaceutical industry with suppliers of raw materials during the 18 months studied (2019 - 2020) have well simulated the behavior of the studied variables (Figure 8).

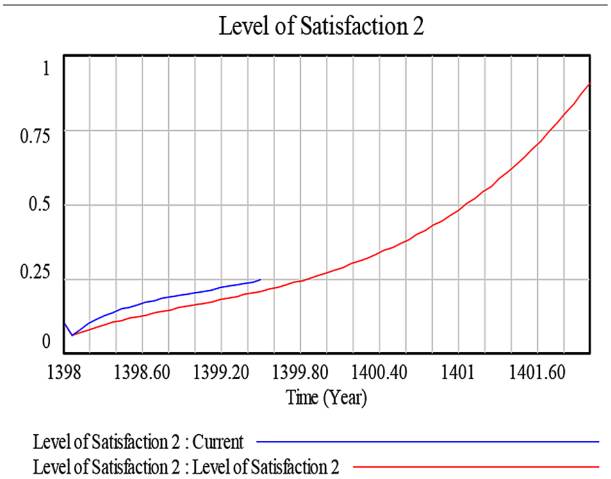


Figure 8. Simulation results and real data for the level of satisfaction of the country's pharmaceutical industry with raw material suppliers (reference: study results)

3.2. Error Calculation Test

In addition to rehabilitating the model's behavior to ensure the result of simulated, the key variables error was calculated by the bellow methods.

3.2.1. Root Mean Square Percent Error

Accordingly, the smaller differences between simulated and real data, the more reliable the simulation results can be. The following formula calculates the error in this method:

$$\text{RMSPE} = \sqrt{\frac{1}{\Theta}\sum_{i=1}^{\Theta}\left(\frac{y_{T+i}^{s} - y_{T+i}^{a}}{y_{T+i}^{a}}\right)^{2}} \times 100$$

Where y_{T+i}^{S} confirms the results of the model variable simulation, y_{T+i}^{a} confirms the real data, and θ indicates the number of observations. Accordingly, the closer the least squares error is to zero, the less the error.

3.2.2. Identifying the Root Error

U-Theil's is another method for measuring the deviation of simulated values from real data, which is calculated by the following formula:

$$UT = \sqrt{\frac{\frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{s} - y_{T+i}^{a})}{\frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{s})^{2} + \frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{a})^{2}}}$$

3.2.3. Calculating The Root Error

Desired the importance of error in predicting, knowledge of the resources of error in reducing it can be very effective in increasing trust in the results of the model.

3.2.3.1. Base Error

when the model outputs are not the same as the data, this error occurs, which is called a systematic error.

3.2.3.2. Deviation Error

This is achieved when the real and simulated data variances are very different. The root error may be systematic or unsystematic.

3.2.3.3. Inequality of Covariance Error

when the results of the model and the data are not correlated, this error occurs, called an unsystematic error (... 2000). The following formula is used to calculate the root error.

$$U^{m} + U^{s} + U^{c} = 1$$

$$U^{m} = \frac{(\overline{y^{s}} - \overline{y^{a}})^{2}}{\frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{s} - y_{T+i}^{a})^{2}}$$

$$U^{s} = \frac{(SDS - SDA)^{2}}{\frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{s} - y_{T+i}^{a})^{2}}$$

$$U^{c} = \frac{2 \times (1+r) \times (SDS \times SDA)}{\frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{s} - y_{T+i}^{a})^{2}}$$

$$\frac{(\bar{y}^{s} - \bar{y}^{a})^{2} + (SDS - SDA)^{2} + (2 \times (1+r) \times (SDS \times SDA))}{\frac{1}{\Theta}\sum_{i=1}^{\Theta}(y_{T+i}^{s} - y_{T+i}^{a})^{2}} = 1$$

$\bar{y}^{s} - \bar{y}^{a}$ is the difference between the average of simulation information and the average of real information. In the above equations, SDS and SDA represent standard deviation simulation and standard deviation actual, respectively, and r is the correlation coefficient between these two data. The calculation results of each error calculation test according to the key variables studied in the simulation model have been shown in Table 2. According to the error calculation test results, the min square error for each key variable studied is close to zero, confirming an insignificant difference between the real and simulated data. The error computed for each key variable of human resource training, inventory management, and the cost of resources and services is 0.09110, 0.10173, and 0.08381, respectively. As a result, it can be said that the error of the studied variables is at the standard level.

Table 2. Error Calculation Test

Variable	Test		
	Human Resources Training	**Inventory Management**	**Cost of Resources and Services**
RMSPE	0.09110	0.10173	0.08381
UT	0.08371	0.04511	0.05106
Um	0.13183	0.17441	0.16192
Us	0.20217	0.30118	0.28919
Uc	0.66518	0.52440	0.5589
Um + Us + Uc	1	1	1

[z] Abbreviation: RMSPE, root mean square percent error

3.3. Sensitivity Analysis

Sensitivity analysis in system dynamics confirms to what extent the key variables of the research are sensitive to the parameters studied in this study. Accordingly, in this section, the selected parameters that directly affect the variables have been changed to a certain ratio in a certain range for their effects on the variables. In this regard, the sensitivity of the satisfaction of the country's pharmaceutical industry with the suppliers of raw materials to the changes in responding to the request for immediate delivery will be investigated. The above parameter has been changed by ± 30%, and its effect on the satisfaction of the country's pharmaceutical industry with raw materials suppliers has been investigated. The results of the sensitivity analysis showed that a 30% change in response to the request for immediate delivery would cause the satisfaction of the country's pharmaceutical industry with the suppliers of raw materials at the probability levels of 50, 75, 95, and 100% in the yellow, green, blue and gray, respectively (Figure 9).

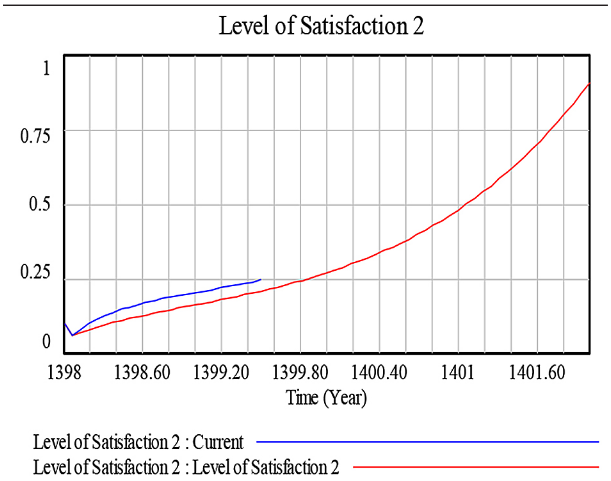


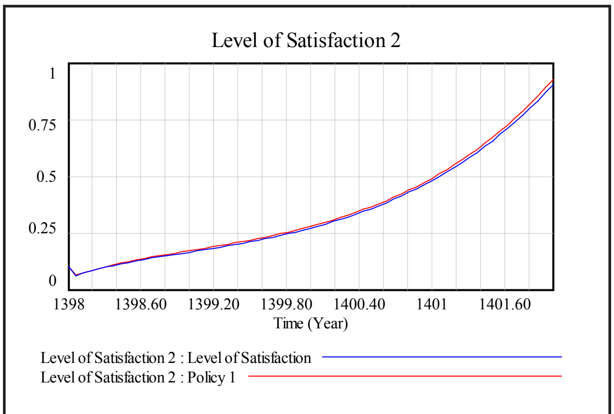
Figure 9. Changes in the level of satisfaction of the country's pharmaceutical industries with raw material suppliers (reference: study results)

3.4. Policy Making to Optimize the Key Variables of the Model

3.4.1. Scenario 1

Prediction of a reduction by 1% in schedule pressure during the studied period and its effect on the satisfaction of the country's pharmaceutical industry with raw materials suppliers.

According to the simulation results in Figure 10, a reduction of 1% in the schedule pressure will allow the country's pharmaceutical industry to increase satisfaction with suppliers of raw materials by an average of 1.23%. It should be noted that the red line in the Figures refers to the implementation scenarios.



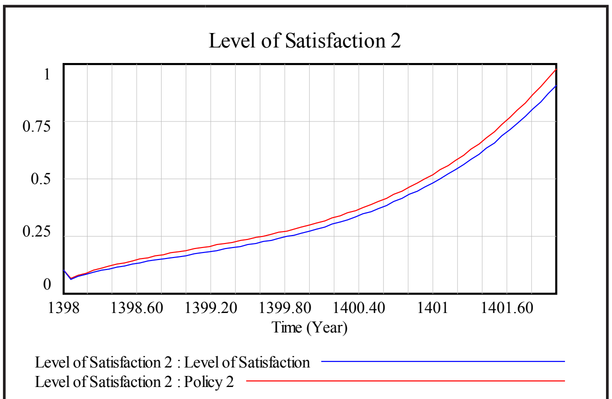
Scenario 1	Base value	Year
0.1490	0.1434	2019
0.2612	0.2536	2020
0.4074	0.3978	2021
0.7877	0.7698	2022
0.9256	0.9045	2023

Figure 10. The effect of a 1 percent reduction in schedule pressure during the period under review and its effect on the level of satisfaction of pharmaceutical industries (reference: study results)

3.4.2. Scenario 2

Prediction of a reduction by 3% in schedule pressure during the studied period and its effect on the satisfaction of the country's pharmaceutical industry with suppliers of raw materials.

According to the simulation results in Figure 11, a reduction of 3% in the schedule pressure will allow the country's pharmaceutical industry to increase satisfaction with suppliers of raw materials by an average of 5.69%.



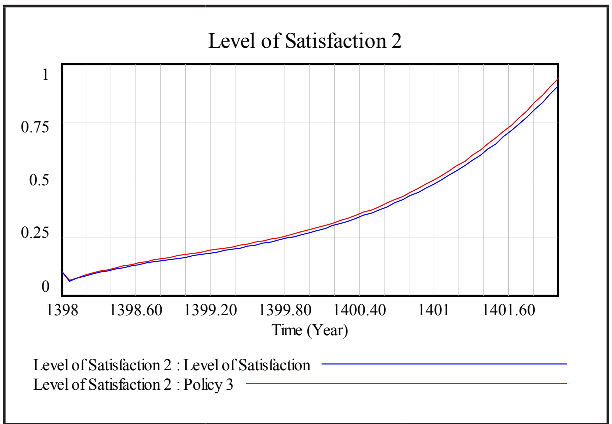
Scenario 2	Base value	Year
0.1773	0.1434	2019
0.3031	0.2536	2020
0.4566	0.3978	2021
0.8750	0.7698	2022
0.9734	0.9045	2023

Figure 11. The impact of a 3% decrease in schedule pressure during the period under review and its impact on the level of satisfaction of the country's pharmaceutical industries with raw material suppliers (reference: study results)

3.4.3. Scenario 3

Prediction of a reduction by 5% in rework and parallel work during the studied period and its effect on the satisfaction of the country's pharmaceutical industry with suppliers of raw materials.

According to the simulation results in Figure 12, a reduction of 5% in rework and parallel work will provide the reasons for this so that the satisfaction of the country's pharmaceutical industry with suppliers of raw materials will increase by 1.84% on average.



Scenario 3	Base value	Year
0.1519	0.1434	2019
0.2654	0.2536	2020
0.4126	0.3978	2021
0.7971	0.7698	2022
0.9368	0.9045	2023

Figure 12. Prediction of a reduction of 5% in rework and parallel work during the studied period and its effect on the satisfaction of the country's pharmaceutical industry with suppliers of raw materials (reference: study results)

4. Discussion

Maximizing the profitability of the supply chain and customer satisfaction is one of the objectives of supply chain management. For this purpose, it is necessary to have a strategy for the coordination and synergy of the chain's components. Hence, reviewing this issue is important because the satisfaction of the parties with the supply chain (supplier and employer) is the basis of the strength of the relationship between these main components and causes the loyalty of the supplier to the employer and the trust of the employer in the supplier at the highest level. It should be noted that increasing satisfaction, in addition to the above, provides the basis for increasing the rate of the supplier's response to the employer to meet his needs. As a result, a reduction in the cost of finding a new supplier for the employer. In other words, it can be said that improving satisfaction in this field will improve the operation rate and reduce side costs in the supply chain. If companies and countries can move their supply chain activities towards more effectiveness and efficiency, they can be expected to gain a sustainable competitive advantage. In this regard, it should be noted that effective management activities have a very special place in realizing this task because it will cause a lot of cost savings.

The present study analyzes the satisfaction of the country's pharmaceutical industry with raw materials suppliers by presenting a comprehensive model. For this purpose, several linear statistical approaches can be used to make it clear. The results of the present study showed that the satisfaction of the country's pharmaceutical industry with suppliers of raw materials this year was 32.38%. By confirming the trend of the model, it can be concluded that the satisfaction of the country's pharmaceutical industry with raw material suppliers will increase to around 90.45 by the end of the study period.

In the present study, the system dynamics approach was used, compared to similar studies that did not pay attention to dynamic relationships. In a study by Rahimian and Rajabzadeh Qatari, the resilience of the supply chain with the approach of complex adaptive systems in Iran's pharmaceutical industry was measured (11). The results provide the basis for analyzing resilience and choosing an effective strategy to reduce supply chain risk for managers of this industry (11). In addition, Sedighpour et al., in research titled "designing and explaining the resilient supply chain model in Iran's pharmaceutical industry," indicated that pharmaceutical industry managers can create and utilize capabilities and strengthen the enablers while reducing the factors that make companies prone to disruptions, to gain the necessary resilience in facing them (1).

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