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Enhancement the Performance of Multi-Level and Multi-Commodity in Supply Chain: A Simulation Approach

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ABSTRACT

In today's global economy, effective supply chain management plays a pivotal role in the success of a business. The repercussions of a business strategy on the entire supply chain remain uncertain until it is implemented. Utilizing simulations offers the opportunity to gauge performance prior to implementing the strategy. The primary aim of employing supply chain simulation is to analyse the effects of different strategies on profit enhancement and cost reduction across all supply chain tiers. This research paper has formulated a discrete event simulation model using Arena software to evaluate and enhance the operational efficiency of the detergent supply chain. The problem involves multiple levels and commodities, encompassing four manufacturers, two intermediate storage warehouses, and four main distributors following an (s, S) inventory control approach. Shortages are permitted, leading to a partial loss or back-ordering of products. The overarching objective is to minimize the overall inventory costs within the system, accounting for holding costs at each tier, managing shortages, and the expense incurred due to lost sales. A range of scenarios are developed to set control parameters, with the evaluation of supply chain performance falling into two main categories: financial and operational considerations.

1. Introduction

Today's business climate is changing rapidly and has become more competitive than ever. Businesses now not only need to operate at a lower cost to compete, but they must also develop their core competencies to be distinguished from competitors and stand out in the marketplace. In today's globally competitive market, every company should perform a rapid response to external stimuli, and no individual company could operate in this competitive market. Therefore, the supply chain and its management are essential factors for successful participation in competitive markets.

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This is also a competitive advantage for companies. A supply chain is a network of organizations in business process performance whose involved at each stage of the chain, including production, distribution, logistics. An integrated supply chain aims to achieve the effective and efficient flow of goods, services, information, money, and decisions to provide maximum value for customers with low cost and high speed. Operational coordination can only result in operating profits, but strategic coordination offers operational and strategic benefits. It is worth noting that, today, organizations, instead of vertical integration, experience "virtual integration." Today, the amount of investment involved in inventory is very high. Control of the asset involved in raw materials, goods in process, and finished goods could have excellent improvement potential. Scientific methods for inventory control can make a very highly competitive advantage for companies. Extra inventory anywhere in the supply chain makes additional costs. On the other hand, inventory shortages at any chain may cause interruptions in production or delays in logistics. Supply chains are frequently subject to unpredictable events that can adversely influence their ability to achieve performance objectives. An inventory system aims to determine to what time and how much order should be placed. This decision should be based on inventory condition, predicting demand, and cost factors. The purpose of modelling the dynamic systems is to understand and perspective the system's relationships to improve the possible system's policies Goodarzian et al. [1]. Transactions within the supply chain is a function of many vital variables that often strongly linked to each other. Dynamic systems help provide a holistic view of the system and identify interrelationships in the whole system. Understanding the entire system and analyzing the dependence between the different components of an integrated system and providing feedback without breaking the relationship between components make the dynamic systems ideal for modelling the supply chain. The advantage of dynamic systems to mathematical models is the study of complex systems with many variables and dynamic environments and interactions between variables. Thus, the dynamic system is an appropriate method to evaluate the performance of the supply chain. In recent years, many different science fields have been used for managing dynamic supply chain problems. Among these, control and System theory has been the most popular tools for solving issues such as uncertainty and delay Shirazi et al. [2]. The main challenges in inventory control of the supply chain are production planning and independent logistics for companies, which often are contradictory Goals. Moreover, individual companies' decisions for the entire supply chain to get private information often are inaccessible to other parties. Also, the essential considerations in any system are identifying control points.

Supply chain network problems can be solved by using two methods; mathematical optimization techniques and simulation methods. Discrete event simulation and system dynamics are two modelling approaches widely used as decision support tools in logistics and supply chain management. Using devices with simulation bases, we could consider the system's dynamism and determine the system's performance with a particular design. Simulation models can only analyses predetermined structures and cannot provide a specific plan themselves. Also, the simulation results are not optimal. Simulation models help determine the proposed plan's performance, but they 'can't choose the best design between many proposed projects. Simulation optimization can be defined as finding the best values of input variables from all possibilities without explicitly evaluating each option. Simulation optimization aims to minimize the resources spent while maximizing the information obtained in a simulation experiment Motevalli-Taher et al. [3]. Computer simulation often used in complex evaluation systems and optimize response. Simulation tools are often used for supporting decision-making on supply chain redesign when logistic uncertainties are in place, building on their inherent modelling flexibility. This paper aims to design a simulation model to improve the operational and financial indicators in a multi-commodity and multi-level supply chain. Another aim is to determine the effect of changes in a supply chain's inventory levels and improve operational parameters. Here, a single-objective mathematical model of mix integer linear programming is proposed that simultaneously considers the facility location problem in addition to the design of the multi-level supply chain. This study examines a multi-commodity and multi-level supply chain network with stochastic demand downstream (level 3) and a predetermined production plan upstream (level 1). level 1 consists of several manufacturers that mainly produce distinct goods and produce common goods. level 2 includes warehouses of distribution centers, and regional distribution centers are located at level 3. level 1 is. Demands for each commodity in each distribution center are stochastic. The production planning unit uses aggregated demand, regional demand, the capacity of the machines, production policies, and other elements to Determine the production Scheduling for each commodity in each commodity component of level 1. goods can be shipped to distribution per centers from either station '1's warehouses and central warehouses of level 2 with different possible prices.

The rest of the paper is structured as follows: Section 2 presents an overview of the basic simulations and related works used in the proposed method. Section 3 introduces the problem definition and mathematic proposed method. In section 4, the simulation method as a solution approach is addressed. The experimental and analysis findings obtained from the proposed method to tackle the best scenarios are discussed in Section 5. Section 6 presents the conclusion of this paper and discusses future work.

2. Related works

Arif et al. [4] stated that supply chains are not entirely discrete and not relatively continuous and developed a hybrid model for the supply chain. They have shown that the discrete simulation has more efficiency for lower layers and operational levels, and integrated modelling would be more suitable for higher-level simulation. They have simulated the flow of information and goods to improve the inventory levels as both discrete and hybrid models and concluded that the hybrid model and its implementation would be more comfortable. Safaei et al. [5] introduced different supply chain simulation fields and developed a comprehensive supply chain model, including getting an order from a customer until delivering the product. Retailer, by selling goods, depending on inventory control policies, orders the distributor and predicts customer demand. It also happens to the distributor, and he sends the order to the supplier. This analysis shows the impact of demand information sharing on the chain is appropriate for medium-term decision-making levels and This model simulates a push system because it predicts the demand. Longo and provide the same model but with a pull system. This model simulates the product flow from the factory to the customer. Designing different inventory control systems in factories, distribution, centers, and retail stores and analyzing various scenarios by analyzing variance and designing tests are features of this model. Also, product flow in the factory has been considered. Arya-sassi et al. [6] that current analytical methods cannot solve problems with many stochastic variables, designed a dynamic system model based on the orders in the supply chain. This model, which simulates the inventory control system and warehouse, has applied various demand scenarios. By assuming the delay for demand satisfaction, this model considers no limit on production, and increasing production does not affect product quality. Another study of dynamical systems for the supply chains has done by Ghasemi et al. [7]. In this research, process cycle, storage, and transfer to the different supply chains have been considered. Since dynamic systems are not suitable for modelling details, these systems have not enough flexibility to simulate the flow of other products and different production systems Rahman et al. [8]. Yu et al. [9] merged DES with linear integer programming and DES Genetic algorithms to build an approach that can rapidly respond to disruption conditions all along the supply chain to plan and monitor transport and distribution processes.

Zheng et al. [10] addressed a method which supply chain systems' dynamic nature and their behavior depend on customers' uncertainty, suppliers, different procurement paths, alternative inventory, etc. Thus, using dynamic system simulation is common. Abdolazimi et al. [11] suggested a statistical bi-objective model for distributing goods in warehouses for block stacking. In this specific case, two aims are targeted at storage allocation: reducing travel distance and optimizing average storage utilization. Arji et al. [12] prepared a comprehensive and dynamic tool for analysis of the supply chain, which is a combination of the Supply chain operations reference (SCOR) model and Arena software. They also reported a development in integrating discrete-event simulation tools and the SCOR method. Zhang et al. [13] introduced the second version of the SCOR model, which is more complete than the previous version. The second version includes more factors such as the return process.

In a recent report, Lacy-Nichols et al. [14] showed how a multi-stage heuristic could be used in a random allocation setup to solve storage and recovery difficulties while taking capacity problems into account. Gupta et al. [15], published an article to study the behavior of a food supply chain with two initiatives, a unique structure and customer demand due to customer concerns and the fear of a health crisis. For the first time, this model studies the mechanisms of some supply chains' behavior under environmental perturbations. This article is based on a dynamic system simulation for a chicken supply chain with bird flu. Asamoah et al. [16] presented an article to simulate the automotive industry supply chain in Portugal. This study aimed to check alternative scenarios to improve supply chain flexibility and understand risk mitigation strategies for supply chain performance. Performance factors are defined for supply chain entities as the sum of costs and preparation time. The simulation model has developed using Arena simulation software and Microsoft Excel. Arena software has interacted with Microsoft Excel using Visual Basic Applications (VBA). Also, Gozgor et al. [17] developed Two-stage stochastic programming with a support model. A simulation-optimization method is improved to solve this challenging problem approximately. Also, the first-stage problem requires explaining a specific multi-facility network design problem using an exact enhanced cut-generation procedure coupled with a column generation algorithm. Rais et al. [18] performed a simulation to demonstrate inventory management and demand diversity to reduce the bullwhip effect in the steel supply chain. This study shows that information sharing can reduce the bullwhip effect in the supply chain. Schöneich et al. [19] developed a simulation model to promote and facilitate the study of design and analysis of wooden pallets supply chain. This model includes uncertainty, interdependencies between chains of the supply chain, and resource constraints. Berning et al. [20] evaluated collaborative performance as a testing tool for identifying the suitable conducive environment for collaboration. We use actual and simulated data to help management decide the number of partners, the level of investment, and industrial partnerships in the supply chain. This approach in the supply chain will help to get the maximum benefit from collaborative relationships. We use simulations to understand SCC performance compared to the new policy. In this study, five factors have used to assess SCC. Necessary information includes the duration of collaboration, investment levels, and several partners. Also, Ma et al. [21] an article analyses the dependencies between supply chain performance (amount of inventory and inventory shortages) and decision parameters. Moreover, supply chain management and supply chain configuration include the number of resources, the capacity of a given node, number of nodes, inventory capacity, distance between nodes, and supply chain levels. Relationships between these variables have been studied by using scenario planning and discrete-event simulation with statistical analysis. This article discusses SC configuration's impact on SC's performance due to different material management policies. Some previous studies have been examined in Table 1.

Table 1
Overview of several related works in multi-commodities supply chain

No	Authors	Objectives	level		commodity		Member (entity)		Modeling and solving methods		Case study	Evaluation factors of chain
			Single-level	Multi-level	Single	Multi	Single-entity	Multi-entity	coding	software		
[22]	Turner et al. (2015)	Product flow-automobile	-	*	*	-	-	*	-	*	Automotive industry of England	Services level- customer satisfaction –inventory level
[23]	Noche et. al. (2016)	Material flows and resource planning	-	*	*	-	*	-	-	Simio	Cement industry	Costs, inventory and lost customers
[24]	Pawlak et al. (2017)	Reduce inventory costs	-	*	-	*	*	-	MATLAB	-	-	Inventory costs
[25]	Kessi et al. (2023)	commodity delivery time and quality	-	*	-	*	*	-	-	STELLA II software	Clothing industry	Transportation costs, inventory costs, the cost of lost sales
[26]	Joshi et al. (2022)	Enhance cold multi-tiers chains	*	-	*	-	*	-	CPLEX	Promodel	Production	Reduction the cot, improve the allocation
[27]	Our research	Cost optimization and Risk Mitigation	-	*	-	*	*	*	CPLEX	Arena	Manufacturing	several critical performance factors

In addition, the simulation approach has been used in the current research, which allows researchers to compare the performance of systems under different conditions and to predict and make decisions and choose the best solution. This approach also saves time and money and is helpful in conditions of uncertainty and high complexity. By reviewing the previous research, research was not found that analyzed several different multi-commodities types of supply chain simultaneously and strategy evaluation using discrete event simulation; Therefore, these cases have been discussed in the current research.

3. Problem Definitions

The current research is quantitative regarding practical results, analytical objectives, and processes. The tool used in this research is simulation, and a discrete event simulation model has been developed. Real data from the Clothes manufacturing factory has been used for the simulation. In this model, based on the Pareto principle, 20% of goods among all the products have been selected, consisting of 10 products. This ten-product produced by four manufacturers which none of them make an expected outcome. Based on the Pareto principle, four sites have been chosen among all local distributors as distributors of the problem. Central warehouses keep excess demands of distributors and when the order of all distributors is greater than the manufacturer's inventory, this shortage will be answered by central warehouses. For example, as in Figure 1 has shown the various levels and different manufacturer and distributer in textile company.

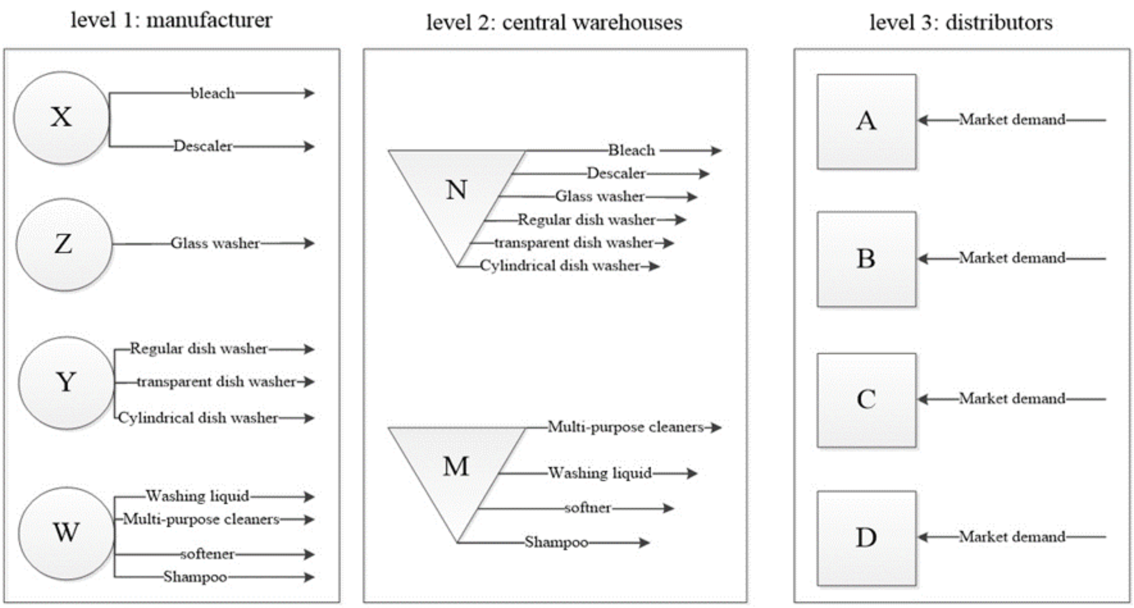

Fig. 1. Overview of the structure of the supply chain

Each customer goes to one of the significant local distributors and places an order. If the distributor's stock is greater than the demand, the customer's need will be answered, and then the distributor's inventory levels will be updated. After responding to customer demand, the distributor controls the ordering point and will place an order if needed. But suppose there is not enough product at d distributor's warehouse. In that case, the customer must wait until goods have sent from the manufacturer or the central warehouses to the distributor only if there is enough inventory to meet the distributor's order. In these cases, a backlog occurs in the chain, and as soon as the arrival of goods, lagged orders will respond. The first step tried to meet the demand of distributors by sending goods directly from manufacturers. If the manufacturer cannot respond to distributors' requests in the second step, goods will be indirectly from the central warehouse. Direct shipping reduces from costs of dock and loading and other transportation costs. In the case of the absence of goods at the distributor, in the first stage, distributor inquiries from manufacturer to see whether there are enough goods to meet customer's demand or not? If there are enough goods, they will be sent. But, if the manufacturer hasn't enough goods, distributor inquiries from central warehouses to see whether there is enough requested item or not? If goods are available, they will be sent, and otherwise, this customer is a lost sale. In this study, we could also meet the demand by a combination of manufacturer and central warehouses.

This research is based on the following assumptions:

1) In this paper, the supply chain consists of three levels. The first level consists of 4 distributors as X, Y, Z, and W. The second level includes two central warehouses as N and M, and the third level consists of 4 distributors as A, B, C, and D.

2) Demand at the retail level has been considered deterministic and stochastic, determined by a uniform distribution.

3) Amount of output of manufacturers has considered as both deterministic and stochastic with a uniform distribution.

4) simulation has been performed over 90 days.

5) Each supplier could produce only one product.

6) Each manufacture could send its extra produced goods to only one of the central warehouses.

7) There is no limitation on the capacity of central warehouses.

8) There are demands for all ten products at each distribution centre.

9) Periodic review policy (s, S) has considered each distributor, and inventory review cycle time is one day.

10) The lead time for delivery from manufacturers to distributors and central warehouses is considered 0.

11) Facing shortages and lost sales are allowed in the problem.

2.1 Mathematical Modelling

For the model's numerical solution, we use the following notations. Note that variables are defined in this article annually, although any other time measures can be utilized. In this article, designing a multi-commodity distribution chain considering a simulation model, including multiple production plants, warehouses, inventory, and retailers (including customers and service chain), is investigated to minimize the total cost. Hence, we define a basic mathematical model to view multi-commodity distribution quickly. The steps of this research are as follows:

Step 1: First, we will design a model that shows workflow in the supply chain according to sources, customer demand, amount of production at each unit, constraints, and performance factors.

Step 2: This section will present a simulation of the supply chain model according to assumptions and the previous section's data. The simulation has been designed for both deterministic and stochastic conditions.

Step 3: In this section, we will study the model's accuracy for both deterministic and stochastic conditions.

Step 4: In this section, we will define the functional parameters. The results of the designed scenarios will be presented and compared based on these factors.
Step 5: In this section, we will design different scenarios in Arena software.
Step 6: Once the scenarios were implemented in software, in this section, the results of performance factors will be compared by using tables and graphs.
Step 7: Performing various tests using SPSS software.
Step 8: Conclusions, expressing limitations and Suggestions for Future Researches.

Index sets:

N Set of customers/customer zones.

M Set of possible sites for warehouses.

L Set of suitable targets for plants

R Set of ranges of resources available for future warehouses

H Set of levels of service accessible to possible plants

I Index of customers/customer zones

J Index of possible sites in warehouses

O Set of product units

K Index of possible sites for plants

Parameters:

C_{jio} Cost of providing one unit of product o from the warehouse at site j to customer i

C'_{kjo} Cost of supplying one unit of product o from the plant at site k to the warehouse at site j

$\grave{C}_{kio}$ Cost of supplying one unit of product o from the plant at site k to customer i

F_j^r Set cost per unit of time to operate and support a warehouse at site j with a capacity level r

G_k^h Set cost per unit time to set up and run a plant at sites k with capacity level h

a_{io} Request per unit time for goods o of customer i

b_{jo}^r Volume with level r for the possible warehouse at the site j for product o

e_{ko}^h Volume with level h for the possible plant at site k for product o

b_j^r Volume with level r for the possible warehouse at site j

e_k^h Capacity with level h for the possible plant at site k

T The coverage range for factories

$\acute{T}$ The coverage range for warehouses

d_{ij} The length between customer i and place of possible warehouse j

d'_{ik} The length between customer i and place of possible factory k

d'_{jk} The length between the location of possible warehouse j and the place of possible factory k

Decision Variables:

X_{jio} The section of demand for product o by customer i delivered from the warehouse at site j

Y^{r}_{kjo} The section of shipment of product o from the plant at site k to the warehouse at site j with the capacity level r

Z_{jio} The section of demand for product o in customer zone i delivered from the plant at site k

U^{r}_{j} If a warehouse with capacity level r is located at the site j, $=\ 1$ otherwise $=\ 0$

V^{h}_{k} If a plant with capacity level h is located at site k, $=\ 1$ otherwise $=\ 0$

P_{jk} If the distance between customer i and the location $of\ the\ factory, k\ is\ equal\ = 1, otherwise = 0$

S_{jk} If the distance between the location of warehouse j and the location of factory $= 1$, otherwise $= 0$

W_{ij} $if\ the\ distance\ between\ customer\ i\ and\ the\ location\ of\ warehouse\ j = 1, otherwise\ = 0$

S_{jk} $if\ the\ interval\ between\ the\ place\ of\ warehouse\ j\ and\ the\ place\ of\ factory\ k\ is = 1, otherwise\ = 0$

P_{jk} $if\ the\ interval\ between\ customer\ i\ and\ the\ location\ of\ the\ factory, k\ is = 1, otherwise\ = 0$

The problem is formulated as followed, based on the above definitions and notation.

$$\text{Min}\quad Z_p = \sum_{i\in N}\sum_{j\in M}\sum_{o\in O} C_{jio} a_{io} X_{jio} + \sum_{r\in R}\sum_{j\in M}\sum_{k\in L}\sum_{o\in O} C_{kjo} b^{r}_{j} Y^{r}_{kjo} +$$

$$\sum_{r\in R}\sum_{j\in M}\sum_{k\in L} C'_{kio}.a_{io}.Z_{kio} + \sum_{j\in M}\sum_{r\in R} F^{r}_{j} U^{r}_{j} + \sum_{k\in L}\sum_{h\in H} G^{h}_{k} V^{h}_{k} \tag{1}$$

$$\sum_{j\in M} W_{ij}\, X_{jio} + \sum_{k\in L} P_{ik}\, Z_{kio} = 1, \qquad \forall i \in N, \quad \forall o \in O \tag{2}$$

$$\sum_{k\in L} S_{jk}\, Y^{r}_{kjo} = U^{r}_{j}, \qquad \forall j \in M, \quad r \in R, \quad \forall o \in O \tag{3}$$

$$\sum_{o\in O}\sum_{i\in N} X_{jio}\, W_{ij} a_{io} \leq\ b^{r}_{j} U^{r}_{j}, \qquad \forall j \in M \tag{4}$$

$$\sum_{o\in O}\sum_{i\in N} X_{jio}\, W_{ij} a_{io} \leq \sum_{r\in R}\sum_{k\in L}\sum_{o\in O} Y^{r}_{kjo} S_{jk}\, b^{r}_{j} U^{r}_{j}, \qquad \forall j \in M \tag{5}$$

$$\sum_{o\in O}\sum_{i\in N} Z_{kio}\, P_{ik} a_{io} + \sum_{r\in R}\sum_{j\in M}\sum_{o\in O} b_j^r\, S_{jk} Y_{kjo}^r \le \sum_{h\in H} e_k^h\, V_k^h, \qquad \forall k \in L \tag{6}$$

$$\sum_{r\in R} U_j^r \le 1, \qquad \forall j \in M \tag{7}$$

$$\sum_{h\in H} V_k^h \le 1, \qquad \forall k \in L \tag{8}$$

$$\sum_{j\in M} W_{ij} + \sum_{k\in L} S_{jk} \ge 1, \qquad \forall i \in N \tag{9}$$

$$\sum_{k\in L} S_{jk} \ge 1, \qquad \forall j \in M \tag{10}$$

$$W_{ij} \le \frac{T_j'}{d_{ij}}, \qquad \forall i \in N,\ \forall j \in M \tag{11}$$

$$P_{ik} \le \frac{T_k}{d_{ik}'}, \qquad \forall i \in N, \quad \forall k \in L \tag{12}$$

$$S_{jk} \le \frac{T_k}{d_{jk}'}\,, \qquad \forall j \in M, \quad \forall k \in L \tag{13}$$

$$X_{jio} \le a_{io} W_{ij}, \qquad \forall j \in N, \quad \forall K \in L, \quad \forall o \in O \tag{14}$$

$$Z_{kio} \le a_{io} P_{ik}, \qquad \forall i \in N, \quad \forall k \in L, \quad \forall o \in O \tag{15}$$

$$\sum_{r\in R}\sum_{o\in O} Y_{kjo}^r \le \sum_{r\in R} b_j^r\, S_{jk}, \qquad \forall j \in M,\ \forall k \in L \tag{16}$$

$$X_{jio} \ge 0, \qquad \forall i \in N, \quad j \in M,\ o \in O \tag{17}$$

$$Z_{kio} \ge 0, \qquad \forall i \in N, \quad k \in L,\ o \in O \tag{18}$$

$$Y_{kjo}^r \ge 0 \qquad \forall k \in L, \quad j \in M, \quad r \in R,\ o \in O \tag{19}$$

$$U_j^r \in (0,1), \qquad \forall j \in M, \quad r \in R \tag{20}$$

$$V_k^h \in (0,1), \qquad \forall l \in L, \quad h \in H \tag{21}$$

$$W_{ij}^r \in (0,1), \qquad \forall j \in N, \quad j \in M \tag{22}$$

$$P_{ik} \in (0,1), \qquad \forall i \in N, \quad k \in L \tag{23}$$

$$S_{jk} \in (0,1), \qquad \forall j \in M, \quad k \in L \tag{24}$$

The proposed method reduces the technique's time cost, including deliveries to warehouses from the plant, deliveries to consumers from plants, deliveries to warehouses from plants, and warehouses and plants' opening and operation costs. The Constraint Set (2) ensures that warehouses and plants' operations meet all customers' requirements. The collection of constraints (3) guarantees that the requests of all warehouses are met. Sections of constraints (4) and (5) ensure that the customer's total demands fulfilled by the open warehouse do not surpass either the warehouse capacity or the total shipments to warehouses from any available plant. The collection of constraints (6) illustrates plants' capacity issues about their overall shipments to warehouses and customers. Constraint sets (7) and (8) ensure that a warehouse and a plant can each be allocated to a limit of one level of capacity. It is specified in Constraint (9) that at least every customer must be placed within a warehouse or production delivery range. Constraint (10) also notes that at least every warehouse must be placed within a production line coverage range. Constraints (11) to (16) guarantee that the interval between warehouses and plants and the distance between customers and warehouses and plants are within the warehouses' coverage ranges and plants that deliver products. Finally, the constraint sets (17), (18), and (19) implement the limitations of non-negativity on the associated decision variables, while the constraint sets (20), (21), (22), (23), and (24) impose limitations of integrity on the binary variables.

4. Solution approach

For Using input information, an initial simulation of the supply chain model could be provided by the software. In Figure 2, the initial design of the supply chain has presented based on the basic scenario. In this simulated model, the entire process of the supply chain and all assumptions are considered.

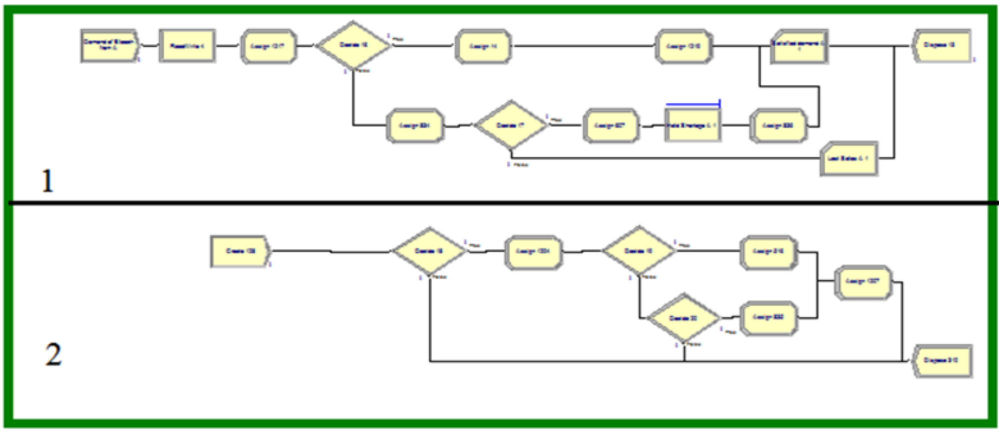

Fig. 2. A simulation outcome of the distributor section in various scenario

In this research, the simulation of the supply chain is backward. It means that we will move from customer to the manufacturer. To simulate the model, First, the distributor level affected for one product, which consists of sections one and sections 2. Section 1 is about receiving an order from the Customer, which is the sales department of the distributor. Section 2 is about inventory levels control at the inventory control unit of the distributor. We will describe each section in detail. The model in Figure 2 simulates all four distributors for each ten demanded commodities by customer. In other words, the whole model has made of 40. In part 1, first, the demand entity has created using Create module. Then, this entity, once a day and for 90 days, will be produced. Then, the demand entity enters to Read Write modules, and the demand of that day has called from Excel file and gets label on-demand entity as a feature. Then, the entity enters to Decide module, and the decision should be taken here. If the inventory level is greater than or equal to demand, the relevant entity passes through the True output. After answering customer demand, the distributor's inventory levels will be updated. However, suppose the distributor's inventory levels are less than demand. In that case, the relevant entity passes through False output and enters into the Assign module. A new order will be placed, equal to the difference between customer demand and distributor's inventory levels. If the answer is True, then the distributor's inventory levels will change in the Assign module according to the following equation:

Inventory Level Distributor A 1-Number Demand Bleach A (25)

Then, the relevant entity enters the Record module to determine distributor's response rate for each product. But if the answer is False, then a new order will be placed in the Assign module according to the following equation:

Remain Number Demand Bleach A + (Number Demand Bleach A-Inventory Level Distributor A1) (26)

Then relevant entity enters into the deciding module to determine the amount of new order for manufacturer's inventory level and central warehouse by using the following equation:

(Inventory Level Factory X 1 + Inventory Level Store N 1) >= Remain Number Demand Bleach A (27)

If the answer is true, then the relevant entity enters into the holding module. Appropriate entity stays in this module until distributor's inventory level increases. This amount of time is equal to the following equation:

Inventory Level Distributor A 1 >=Remain Number Demand Bleach A (28)

Until the entity stays in the hold module, a shortage occurs in the system. After removing the need, the relevant entity enters into the Record module, and it will be added to the distributor response rate. But if the answer is False, then lost sale occurs in the system. As previously noted, the second part of the distributor simulation is about the inventory control system for the distributor. In this part, we create a new entity using a develop module that daily checks the distributor distributor's inventory level for each product. This new entity enters into the decide module, and if the condition is True, then a new order will be placed as much as needed. Otherwise, no charge will be placed.

Inventory Level Distributor A 1 < Little s (1,1) (29)

At this stage, the amount of order determines in the Assign module. As previously described, inventory control policies apply at this stage. The chain's control policy is a continuous review policy, and the ordering policy is (s, S) policy.

BIG S (1,1) - Inventory Level Distributor A 1 (30)

First, to request a new order, its inquiries from the manufacturer, and if the manufacturer has not enough inventory, it will be inquired from the central warehouse. This demand would be a backlog

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shortage if the product's total requested product is available at the manufacturer's inventory or main warehouse. But if we could not meet the request by the sum of the first and second level, then lost sales occurs. First, we check the inventory level of the manufacturer to decide on the module. If the inventory is low, we study the inventory level of the warehouse using the next Decide module. The following equations represent the conditions of Decide modules.

$$\textit{Inventory Level Factory X 1} >= \textit{Shipping Order A 1} \tag{31}$$

$$\textit{Inventory Level Store N 1} >= \textit{Shipping Order A 1} \tag{32}$$

If equation (25-32) is satisfied, the manufacturer could respond to distributor's order. After meeting the ordering, the inventory levels of the manufacturer and distributor should be updated. The inventory level updates by using the Assign module.

$$\textit{Inventory Level Factory X 1} = \textit{Inventory Level Factory X 1} - \textit{Shipping Order A 1} \tag{33}$$

$$\textit{Inventory Level Distributor A 1} = \textit{Inventory Level Distributor A 1} + \textit{Shipping Order A 1} \tag{34}$$

But, if equation (25-32) is satisfied, it means that the central warehouse could respond to distributor's order. After meeting the relevant main warehouse's ordering, the inventory levels distributor must update the inventory level updates using the Assign module.

$$\textit{Inventory Level Store N 1} = \textit{Inventory Level Store N 1} - \textit{Shipping Order A 1} \tag{35}$$

$$\textit{Inventory Level Distributor A 1} = \textit{Inventory Level Distributor A 1} + \textit{Shipping Order A 1} \tag{36}$$

After answering to distributor's order, the order's value must be equal to zero to avoid conflicts at the following cycles. Also, the production section will be simulated as follows. First, we create an entity with a product label. Then, this entity enters into the Read-Write module, and the amount of production has called from an Excel file based on the production schedule, and it gets label on the entity as a feature (Figure 3).

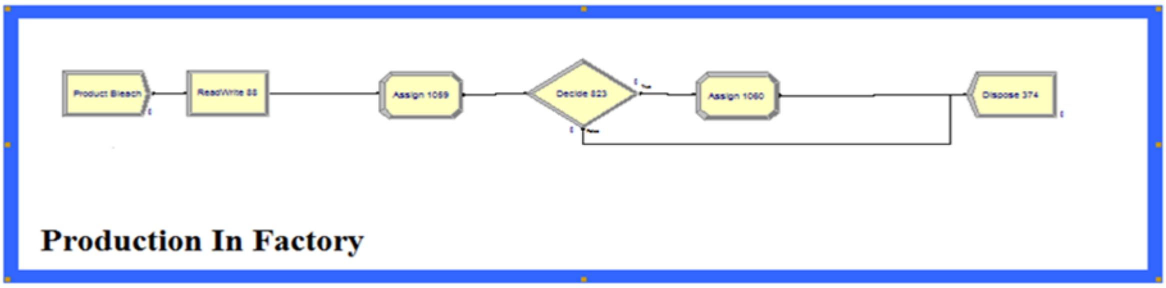

Fig. 3. The simulation view of the manufacturer in factory with various scenario

Now, manufacturer's inventory level must get updated using the Assign module, which obtained from the following equation:

$$\textit{Inventory Level Factory X 1} = \textit{Inventory Level Factory X 1} + \textit{Number Product Bleach} \tag{37}$$

Then, once production reached a certain amount (S), a percentage of that (R) will be sent to the central warehouse.

$$\textit{Inventory Level Factory X 1} = \textit{Inventory Level Factory X 1} - \textit{Release X 1} \tag{38}$$

$$\textit{Inventory Level Store N 1} = \textit{Inventory Level Store N 1} + \textit{Release X 1} \tag{39}$$

According to experts, in addition to basic scenarios, seven more methods are presented. Among them, three strategies have been designed deterministically, and 4 of them have been designed stochastically. To finding the optimal inventory system, all scenarios have been developed based on the ordering inventory level (s) and amount of distributor's order for each commodity. For each scenario, the Supply chain model Simulated in Arena software. All scenarios are in 90 days period and repeated ten times for each scenario (Table 2). Since meeting customer demand is one of the most critical parameters in network performance, the impact of demand, production, and ordering policies are discussed in different scenarios. Ordering policies at fourth, fifth, and sixth scenarios are fixed, and the impact of uncertainty is examined. But in the seventh scenario, customer demand and production are the same as the fourth scenario, and ordering policies are discussed.

Table 2
The results of designing different scenarios for simulation

Scenario	Method	Domain	Ordering policies	Parameters of the problem			
Basic scenario	Demand- deterministic	90-110	s=MAX D	650	250	200	130
	Production- deterministic	90-110	S=2s	1300	500	400	260
Scenario 1	Demand- deterministic	80-120	s=2MAX D	1300	500	400	260
	Production- deterministic	90-110	S=2s	2600	1000	8000	520
Scenario 2	Demand- deterministic	80-120	s=2MAX D	1300	500	400	260
	Production- deterministic	80-120	S=1.5s	1950	750	600	390
Scenario 3	Demand- deterministic	90-110	s=MAX D	650	250	200	130
	Production- deterministic	90-110	S=1.5s	975	375	300	195
Scenario 4	Demand- stochastic	90-110	s=MAX D	650	250	200	130
	Production- stochastic	90-110	S=2s	1300	500	400	260
Scenario 5	Demand- stochastic	80-120	s=MAX D	650	250	200	130
	Production- stochastic	90-110	S=2s	1300	500	400	260
Scenario 6	Demand- stochastic	80-120	s=MAX D	650	250	200	130
	Production- stochastic	80-120	S=2s	1300	500	400	260
Scenario 7	Demand- stochastic	90-110	s=0.7 MAX D	455	175	140	91
	Production- stochastic	90-110	S=2s	910	300	280	182

4.1 Simulating method

In order to validate the proposed model, inventory levels of each distributor, central warehouses, and the manufacturer have been checked at the beginning and end of the cycle. To stability, almost the same results with low dispersion are obtained from different simulated scenarios in software. First, to determine the validity of the proposed model, we examined all products separately. Then, validation of all ten products has been confirmed by experts. The following figures (Figures 4-6) show the validity of the model. The following figures show the inventory level in 90 days of simulation. At the beginning of the simulation, the Inventory level is low. We will increase the inventory level to respond to demands on the last days when there is no production during this period. As previously described, the maximum inventory level at warehouses, manufacturers, and distributors is limited, and the central warehouse will store the excess inventory as a buffer. Inventory increasing policy is based on (s, S) system. Now we check the validity of the model for all commodities in the chain. Four charts show the entire chain for manufacturers' inventory levels, and two maps for central warehouse's inventory level, four charts for distributors inventory level, and one chart for inventory level of the entire chain.

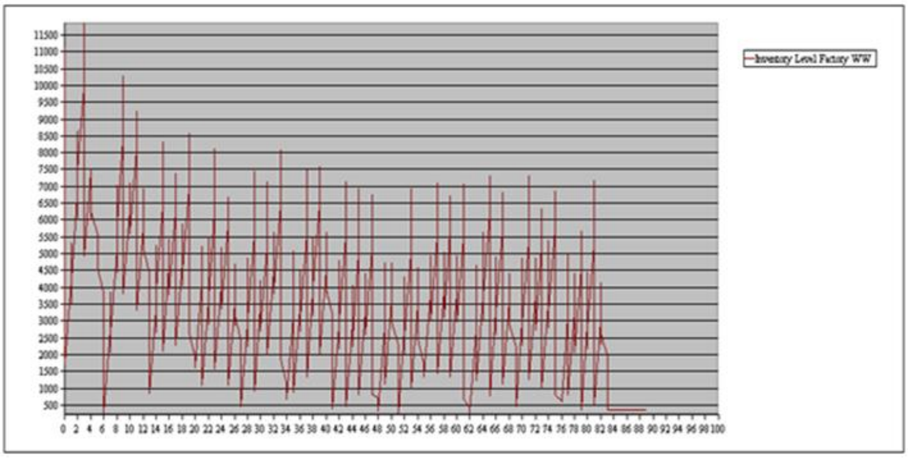

Fig. 4. The validation of inventory level for manufacturer

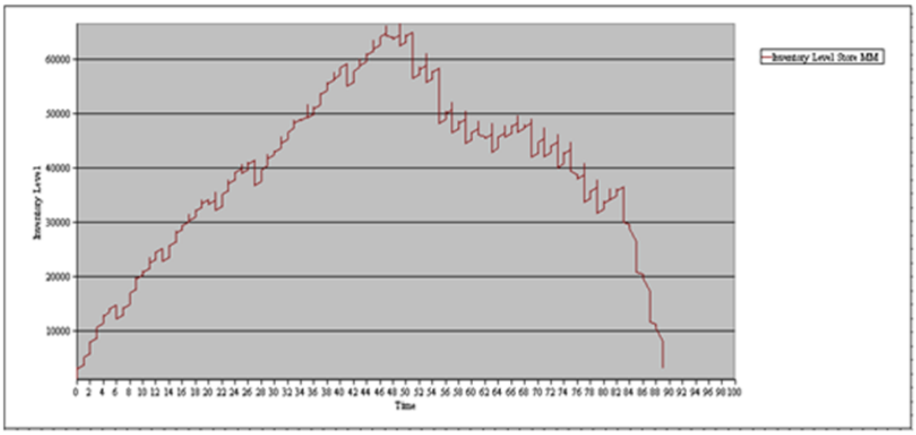

Fig. 5. The validation of inventory level for main warehouse

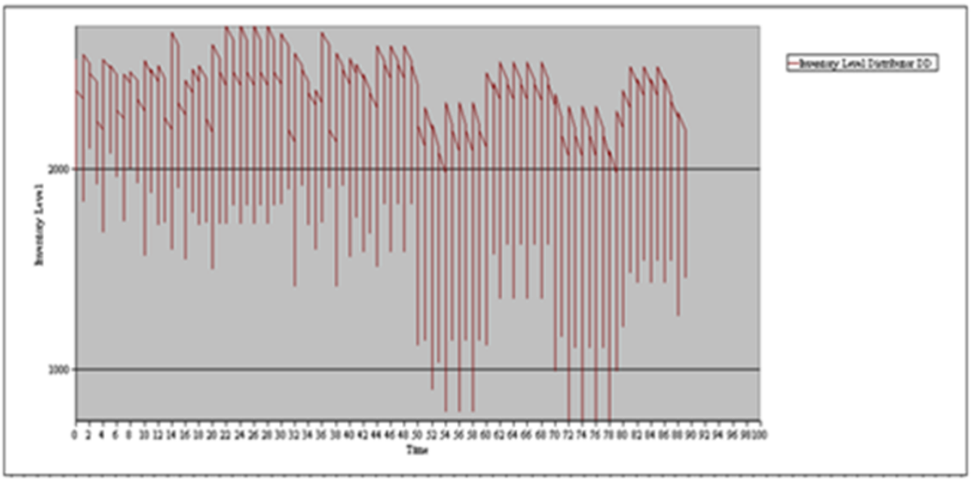

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Fig. 6. The validation of inventory level for distributor

After modelling the chain using Arena simulation, two categories of factors have determined the evaluation of the supply chain's performance. The first category includes five financial, and the second contains eight functional aspects. These factors have been extracted from other scientific researches (Table 3).

Table 3
The factors for evaluation of supply chain performance

Financial factors	**Financial factors**
Average inventory level for distributors	Holding cost for distributors
Average inventory level at warehouse	storage Cost
Average inventory level for manufacturers	Maintenance costs for manufacturers
Maximum inventory level for distributors	backlog cost
Maximum inventory level at warehouse	lost sales cost

5. Research Results & Analysis

In this section, functional factors have been presented after the dynamic simulation of different Arena software scenarios. Supply chain operations have been considered as boarding and on an 8-hour shift. Basic strategy and first to third scenarios are only simulated in software because data are deterministic in the chain. The fourth to seventh scenarios have been affected five times in software because of stochastic data in the chain. The average of simulations has considered an output of the problem. In Table 4, the results of the simulation for each scenario have presented Separately while inventory level of an entire chain based on the basic scenario is illustrated in Figure 7.

Table 4
Outputs of simulated various scenarios with various factors

No	Factors	Basic scenario	First scenario	Second scenario	Third scenario	Fourth scenario	Fifth scenario	Sixth scenario	Seventh scenario
1	Holding cost for distributors	1547125900	3455919600	2910248400	1249807700	2362067360	2355473080	2350640080	1604473800
2	Warehouse storage Cost	7274990800	6126432000	6323615200	7639669800	7093704620	7165143760	6933085700	8966796240
3	Holding cost for manufacturers	201898800	315990400	194748600	136680900	247078460	249450060	267859800	313041500
4	backlog cost	379400	618400	592100	379400	317060	275720	282940	339820
5	lost sales cost	0	0	0	0	0	0	0	0
6	Average inventory of distributors	14503	46057	38948	21562	24218	24257	24213	16488
7	Average inventory of warehouses	103042	76716	80094	96322	93408	94576	93437	143509
8	Average inventory of manufacturers	2600	6657	3905	2260	4732	4780	5155	7923
9	Maximum inventory of distributors	17268	57416	43179	23078	29050	29133	29164	21005
10	Maximum inventory at warehouses	162959	134358	138022	155601	150479	149682	146239	242646
11	Maximum inventory of manufacturers	17892	18988	10963	15104	14781	15334	15252	26972
12	Backlog Percentage	0.0651	0.1475	0.113	0.0651	0.06434	0.06508	0.06064	0.0854
13	lost sales Percentage	0	0	0	0	0	0	0	0
	Total cost	9024394900	9898960400	9429204300	9026537800	9703167500	9770342620	9551868520	10884651360

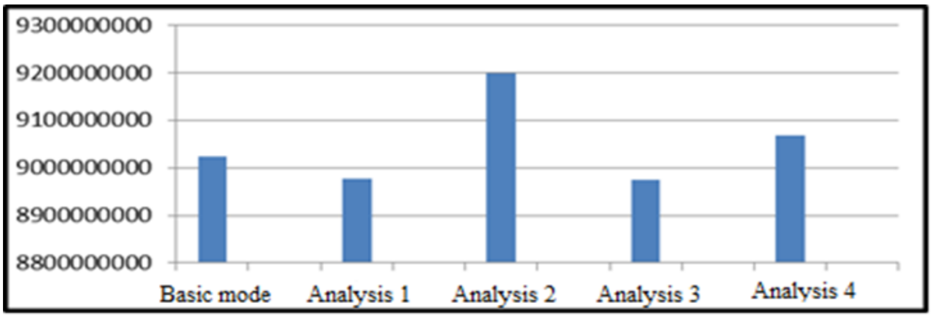

Fig. 7. The inventory level of an entire chain based on the basic scenario

5.1 Sensitivity Analysis

Sensitivity analysis determines the sensitivity of the optimal solutions to specific changes in the original model. This analysis aims to study the impact of the possible changes in parameters on the optimum solution. The primary purpose of sensitivity analysis is to identify sensitive parameters to estimate them more accurately. Here we have chosen some of the parameters for sensitivity analysis. These parameters are Changes in inventory level for releasing goods from factory to central warehouse (*Sendhi*) and releasing goods for sending to the central warehouse (*Releasehip*). The changes have been applied to the basic scenario, and the results are displayed in Table 6. Sensitivity analysis was used to investigate the effect of changing the variables of the simulation model, including the time interval between the occurrence of two commodities, the duration of the transportation, the amount of daily production, and the daily order size on the outputs of the simulation models (performance measures), including the average response rate, the total cost of back demand and the total cost. The results are presented in Table 5 below.

Table 5
The different analysis for sensitivity analysis of the basic model

Factor	Basic value	First analysis	Second analysis	Third analysis	Fourth analysis
Send $_{hi}$	1000	1200	1000	900	1100
Release $_{hip}$	700	700	900	600	800

Due to these results, it is clear that inventory level parameters for releasing goods from factory to central warehouse (Sendhi) and removing goods for sending to the central warehouse (Release hip) have no effect on Backlog Percentage and lost sales percentage. It only changes the inventory level on central warehouses and distributors. By considering inventory cost at each station, the first and third sensitivity analysis's total cost is less than others.

Following analysis has been made to find the best scenario which minimizes all factors. In this paper, eight scenarios have been studied, of which four are deterministic. Another four scenarios are stochastic. Our goal is to find the best scenario for each factor. To achieve this goal, first, we choose the best scenario of deterministic scenarios (a scenario in which its factor is less than others). Then, we choose the best strategy between all four stochastic scenarios using Statistical methods (such as analysis of variance, parametric post-hoc tests, non-parametric Wilcoxon signed rank tests and goodness of fit tests). Then, we select one scenario from deterministic scenarios and one scenario

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from stochastic scenarios using Statistical methods such as t-test. Then we will compare them to each other.

Table 6

The results of output of sensitivity analysis

No	Factor	Fourth analysis	Third analysis	Second analysis	First analysis	Basic value
1	Holding cost for distributors	1547125900	1547125900	1547125900	1545608900	1547125900
2	storage Cost for warehouse	7274990800	7072312600	7419123800	7046288200	7221217200
3	Holding cost for manufacturers	201898800	357841600	231674700	382370600	298860600
4	backlog cost	379400	379400	379400	379400	379400
5	lost sales cost	0	0	0	0	0
6	Average inventory of distributors	14503	24157	24157	24146	24157
7	Average inventory of warehouses	103042	89584	91689	89421	90546
8	Average inventory of manufacturers	2600	6405	4300	6755	5442
9	Maximum inventory of distributors	17268	28896	28896	28536	28896
10	Maximum inventory at warehouses	162959	147455	148069	146719	147144
11	Maximum inventory of manufacturers	17892	18189	11562	18628	15952
12	Backlog Percentage	0.0651	0.0651	0.0651	0.0651	0.0651
13	lost sales Percentage	0	0	0	0	0
	Total cost	9024394900	8977659500	9198303800	8974647100	9067583100

To illustrate this process, the following steps should be done. First, we examine the significance of differences between scenarios 5 to 8 using variance test analysis (or an equivalent non-parametric test). After determining the optimum scenario among these four scenarios (using post-hoc tests), it compares the best scenario among scenarios 1 to 4. The process of choosing the best scenario from scenarios 1 to 8 is shown in Table 7.

Table 7

The results of best choice of the best scenario

<table>
<tr><th rowspan="2">Factor</th><th>Shapiro-Wilk</th><th>assumption of homogeneity of variance</th><th>Best selection</th><th rowspan="2">Parametric or non-parametric</th><th colspan="2">assumption of equality of average of factor in scenarios</th><th>Selecting best stochastic scenario</th><th rowspan="2">t-test</th><th rowspan="2">Selecting best scenario</th></tr>
<tr><th>Sig.</th><th>Sig.</th><th>deterministic scenarios</th><th>Variance</th><th>Kruskal–Wallis</th><th>Tukey test</th></tr>
<tr><td>Total cost</td><td>0.069</td><td>0.153</td><td>1</td><td>parametric</td><td>0.000</td><td></td><td>5,6,7</td><td>0.000</td><td>1</td></tr>
<tr><td>Average inventory of distributors</td><td>0.004</td><td>0.02</td><td>1</td><td>non-parametric</td><td>-</td><td>0.01</td><td>5,6,7</td><td>0.000</td><td>1</td></tr>
<tr><td>Average inventory of warehouses</td><td>0.001</td><td>0.05</td><td>2</td><td>non-parametric</td><td>-</td><td>0.006</td><td>5,6,7</td><td>0.000</td><td>2</td></tr>
<tr><td>Average inventory of manufacturers</td><td>0.039</td><td>0</td><td>4</td><td>non-parametric</td><td>-</td><td>0.003</td><td>5,6,7</td><td>0.000</td><td>4</td></tr>
<tr><td>Maximum inventory of distributors</td><td>0.87</td><td>0.343</td><td>1</td><td>parametric</td><td>0.000</td><td>-</td><td>5,6,7</td><td>0.000</td><td>1</td></tr>
<tr><td>Maximum inventory at warehouses</td><td>0</td><td>0.01</td><td>2</td><td>non-parametric</td><td>-</td><td>0.002</td><td>5,6,7</td><td>0.002</td><td>2</td></tr>
<tr><td>Maximum inventory of manufacturers</td><td>0.208</td><td>0</td><td>3</td><td>non-parametric</td><td>-</td><td>0.008</td><td>5,6,7</td><td>0.000</td><td>3</td></tr>
<tr><td>Backlog Percentage</td><td>0.301</td><td>0.47</td><td>1,4</td><td>parametric</td><td>0.001</td><td>-</td><td>5,6,7</td><td>0.326</td><td>1,4,5,6,7</td></tr>
<tr><td>System performance</td><td>0</td><td>0.05</td><td>4</td><td>non-parametric</td><td>-</td><td>0.002</td><td>5,6,7</td><td>0.000</td><td>4</td></tr>
</table>

It should be noted that all tests have been performed at a significance level of 0.05. Since choosing the best scenario from all stochastic scenarios with respect to each factor is a one-way analysis of variance test for checking the assumption of this factor's equality in all scenarios, it is necessary to check the basic assumptions of these parametric tests. Two basic assumptions in the one-way analysis of variance test are the normality of the random residual and the assumption of homogeneity of variance in the four scenarios. The results of these tests are displayed in table 7, respectively.
For small samples (less than 50), the Shapiro-Wilk test is more appropriate. Hence, we use this test to check the normality assumption. According to Table 7, the normality assumption for residuals of variance analysis has been rejected for factors 6, 7, 8, 10, and total cost factors. The assumption of variance is rejected for factors 6, 7, 8, 10, 11, and the real cost factor. Hence, according to the Shapiro-Wilk test and homogeneity of variance of residuals, we use non-parametric methods instead of parametric analysis of variance techniques to minimize factors 6, 7, 8, 10, 11, and total cost factors Table 7.

6. Conclusions & Future studies

This study aimed to design a simulation model to assess and improve multi-level and multi-commodity supply chain performance factors. For this purpose, we considered a multi-level and multi-commodity supply chain in both deterministic and stochastic conditions. In the deterministic case, all parameters have been considered deterministic. In the stochastic case, parameters for daily demand for each distributor and amount of daily production at each manufacturer were considered stochastic. The purpose of supply chain simulation is to study the impact of different inventory policies on the entire supply chain and reduce costs. In this paper, first, we presented the workflow process in the supply chain. Then, by collecting the required data, we simulated an initial model using Arena software. Then, other models or scenarios are designed and conducted based on the original model. The performance of the system was analyzed due to several critical performance factors. We have designed seven scenarios due to different aspects of the supply chain, and after measuring performance factors, we compared these scenarios to the basic scenario. The results have shown that we could improve performance by changing the ordering level (minor) and distributor's order (big S). The results also indicate that the increasing uncertainty (standard deviation) leads to higher inventory levels to keep customer satisfaction. Furthermore, increasing uncertainty in demand and production and their changes (factor 8) has more effect on the upstream of the supply chain. By decreasing the ordering level and number of orders, we could decrease distributor inventory and keep customer satisfaction. This leads to lower holding costs for distributors and also meets all demands. Also, we studied the impact of control policies, which may reduce about 0.5% of all costs, equivalent to approx. 15000 US dollars over three months. So, it could be concluded that, in the case of increasing uncertainty in demand and production, to avoiding shortages in the system and keeping costs at a minimum, we should increase confidence inventory for each member of the chain or continuously review the inventory control policies in the chain. The simulation model, due to having a connection with Excel, has more flexibility than other models. As we have shown before, we could easily change the problem's input data, assess the supply chain, and improve it. Here, the supply chain is multi-level and multi-commodity, which has several members at each level, which it has not been considered in previous researches. This study has some limitations include in:

- Because of the complexity and breadth of the supply chain model, data collection had some limitations.
- In the proposed model, all costs of the chain, including the cost of transport, ordering, and other costs that could affect the supply chain, have been considered.
- The model has been designed as a single period, and we may not face a shortage at the end of the period, which may affect the next period.

For future research recommendations it is suitable that researches consider the supply chain model, we only considered the (S, s) inventory control policy that could be other policies for Designing a multi-period model to gain better results. Also, considering heuristics optimisation beside simulation optimization methods.

Conflicts of Interest

The authors reported no potential conflict of interest.

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