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Ranking periodic ordering models on the basis of minimizing total inventory cost

Mohammadali Keramati[a] and Vahid Bahmani[b*]

[a]*Assistant proffessor, Arak Branch, Islamic Azad University, Arak, Iran*
[b]*Departement of System Management & Productivity, Arak Branch, Islamic Azad University, Arak, Iran*

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ABSTRACT

This paper aims to provide proper policies for inventory under uncertain conditions by comparing different inventory policies. To review the efficiency of these algorithms it is necessary to specify the area in which each of them is applied. Therefore, each of the models has been reviewed under different forms of retailing and they are ranked in terms of their expenses. According to the high values of inventories and their impacts on the costs of the companies, the ranking of various models using the simulation annealing algorithm are presented, which indicates that the proposed model of this paper could perform better than other alternative ones. The results also indicate that the suggested algorithm could save from 4 to 29 percent on costs of inventories.

1. Introduction

In explaining the supply chain, one may describe it as a process and people who are involved in fulfilling customers' needs directly or indirectly. Generally a supply chain consists of five steps including the customers, the retailers, the wholesalers/ distributers, the producers and the suppliers of primary equipment (Chopra & Meindel, 2007). The primary objective of the supply chain management is to build an authentic flow in transferring the material and the services from the beginning to the end of the supply chain. The entire factors required to be authentic include the quality, the quantity, the cost and the delivery time (Hajshirmohammadi, 2008). Having an integrated chain of supply which can deliver the material needed for the final customer adequately and in proper time and place and with the lowest price is considered as the most important objective of the supply chain (Graves &Willems, 2000). Some people estimate that the cost to keep the inventory in every situation is between 20 to 40 percent of the total inventory, annually. Nevertheless, keeping the inventory is essential to increase the level of services to customers and also to decrease the distribution costs (Bollou, 1992). Since every member of the chain faces its general problems, for having a smooth flow of materials there must be a

* Corresponding author.
E-mail address: v.bahmani@ymail.com (V. Bahmani)

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balance on the inventory to prevent any possible shortage while we minimize the inventory. In other words, the inventory must be managed the way to minimize the costs and the confidence on delivery system would not be distracted, simultaneously (Suri, 1998). Thus, this paper compares different periodic order models including the Periodic order Quantity (POQ), the Least Total Cost (LTC), The Least Unit Cost (LUC), Silver-Meal (SM), Wagner Within (WW), and the Lot for Lot (LFL), using the suggested simulating model on the basis of the total cost of the inventory in a three level distributing supply chain including the suppliers, distributors and the producers.

The inventories consist of the primary elements, unfinished items, spare wares and the product through which the correct control can be effective in balancing the present operations. Also making more reliable, dynamic and durable planning against changes plays essential role on having stable supply chain (Muller, 2003). There are also some expenses associated with inventory such as the costs for the lost opportunities, the storage costs, the tax cost, the insurance, etc. On the other hand there are important factors, which lead the tendency of management to care more about the preserving such as giving fast services to the customers, the decrease in the cost of giving orders, benefiting the workforce and the equipment properly, the decrease in transportation costs and the decline in paying to the supplier (AlamTabriz & Sobhanifard, 2013).

To analyze the inventory control system, it is necessary to recognize the inventory costs. In terms of managing and controlling the inventory the main objectives of the management of an organization is to develop the policies, which can minimize the operational costs. Therefore, the managers try to involve a desired amount of financial resources with inventories to make a balance between the costs. As a whole, different types of costs can be divided in four groups including the storage and the preservation costs, the order, installment and initiation costs, the shortage costs and the purchase costs (in case there is a discount) (Hosseini-Baharanchy, 2002).

2. Periodic order models

To review and to determine the best operation between the inventory management methods, primarily it is necessary to give a definition.

2.1. Lot for lot (LFL) method

LFL is a method for lot sizing, where the system regards the net requirements placed for each period as an order quantity. This method is implemented where the maintenance cost is higher than registration and order cost (Khademizarea, 2004). LFL policy minimizes the stock in the storage and thus helps economize on maintenance costs. Nonetheless, order (preparation) costs will be relatively high in this policy due to the great number of orders (Hajshirmohammadi, 2008).

2.2. Periodic order quantity (POQ) method

In this method, the quantity of orders is equal to the consumption of a number of future periods. The consumption of these periods approximately corresponds to the quantity of economic order obtained from the well-known economic order quantity (EOQ). POQ is a model with the best overall performance.

2.3. Least unit cost (LUC) method

In this method, the quantity of orders is equal to the demand of one or more future periods. The quantity of orders and the number of periods that each order covers is not fixed. In this method it is assumed that the use of the stock occurs at the beginning of each period (New, 1975).

2.4. Least total cost (LTC) method

In this method, the quantity of orders is the same as the demand for one or more future periods. The quantity of orders is determined in a way that the ordering costs per unit as is kept, as much as possible, close to the cost of maintenance per unit of products (Dematteis, 1968).

2.5. Least period cost (LPC)

In this method, the quantity of orders is chosen in a way that the same characteristic of EOQ method for regular demand is repeated, that is, in a way that the total cost per time unit is minimized for the duration that the order covers (Silver & Meal, 1973). It is shown Silver-Mill method generally operates better than the least unit cost (Baker, 1989).

2.6. Wagner-Within (WW) Algorithm

This algorithm, which is designed based on dynamic programming, is an optimization technique. This method aims to investigate the consumptions of all the periods of planning vision at each period and makes decisions based on the terms of planning horizon. Obviously, the number of possible combinations increases with an increase in the number of planning vision programs. In this method, it is assumed that the shortage of stock is not permitted and the initial stock is zero (Wagner & Within, 1985; Kulkarni & Rajhans, 2013).

Considering the existing studies there has been no ranking for the periodical ordering models, which makes the present paper new in this term. To do so it is necessary to introduce the most famous models and policies of the inventory management and specify the objectives and approaches for each one. Afterwards, the approaches expected in this area must be extracted and finally considering such elements the new methods in this area must be introduced and analyzed. Fig. 1 shows the process of the research:

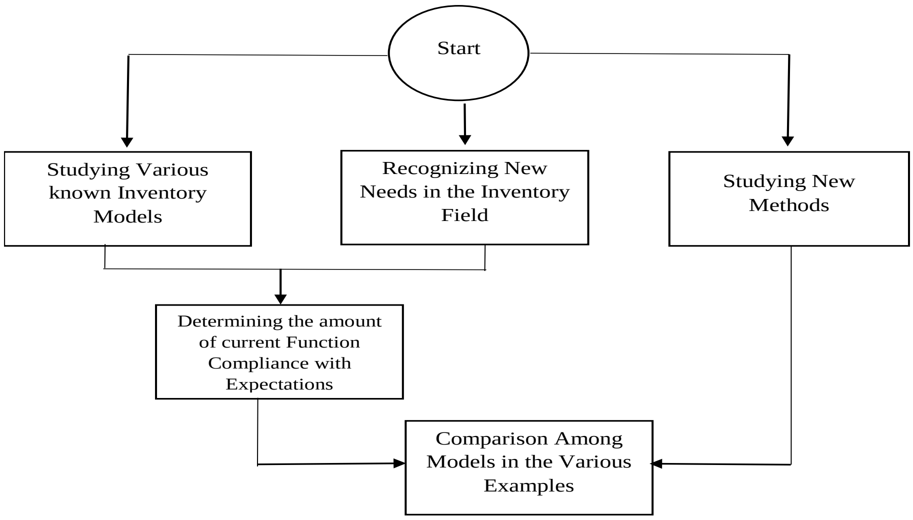

Fig. 1. The process of the research

These areas will be reviewed and introduced following.

3. The methodology and modeling

3.1. Method

This research can be counted as of the applied ones in terms of objective and library based in terms of data collection method and in terms of the kind it is classified on the basis of quantitative studies.

3.2. Reviewing the methods in the existence of a distributor

The data related to 8 items of the inventory are achieved via simulating method from article (Bai & Liu, 2014). But because of the randomness of the parameters of the issue, Monte Carlo simulation is used in order to create data.

Table 1
The data of the selected items existed

Item	Data
The item with the highest annual value	141349769
The item with the lowest annual value	185286
The item with the highest annual consumption	2000
The item with the lowest annual consumption	18
The item with the highest cost unit	72001.63275
The item with the lowest cost unit	360.6395806
The item with the most delivery date (days)	9
The item with the least delivery date (days)	3

Table 2
The characteristics of simulating

Characteristics number	Statistics type	Number in each simulation	Simulations number
5	Average	25	12

As can be seen from Table 2, the 5 main features of each order which must identically exist in different ordering models and supply must be in average as a result of 12 simulations where in each one 25 averages have been simulated. The significant note is that to perform each average correctly the random average has been used.

3.3. The supply chain modeling

In this research, a supply chain is introduced by considering uncertain demands and the characteristics of the supply chain is as follows:

A three-level supply chain includes the suppliers, the producers and also the distributors which must review different demands in various regions. It is also possible that demand was not met and also goods would be postponed for the next period. Also there is no transportation possibility between the producing centers and every producer center must only use its own store for preserving and also during the planning it cannot change its inventory policy. The costs related to orders, holding costs and ordering are of the most crucial parameters during the issue. On the basis of this model, the possibility to compare different models of the order and the inventory preserving has been provided. The following mathematical model starts with introducing the variables and the parameters and then introduces the mathematical modeling.

Table3
Indexes, parameters and variables

Indexes	
i	The displayer of the chosen ties as hub
j	The displayer of not chosen ties as hub
Parameters	
$Demand_{j,b}$	Demand of point *b* from point *j* which is a periodical and unreliable parameter
Variables	
D_i	The maximum capacity of the hub point *i* to transfer the demand
Z_i	If the tie *i* is chosen as hub
$x_{i,j}$	If the *j* tie is connected to *i* hub and is the only transfer way for *j*
$x_{i,j,s,b}$	If the transfer existis between the two non-hub ties *i*, *j* from the two middle group *i* and *s*

The mathematical model of this research is as follows:

$$\min \quad \varphi$$
subject to

$$x_{i,j} \leq Z_i \qquad \forall i, j \tag{1}$$

$$Z_i \leq \sum_{j} x_{i,j} \qquad \forall i \tag{2}$$

$$x_{i,j,s,b} \leq x_{i,j} x_{s,b} \qquad \forall i, j, s, b \tag{3}$$

$$\sum_{j} \sum_{b} \sum_{s \neq b} x_{i,j,s,b} Demand_{j,b} \leq D_i \qquad \forall i \tag{4}$$

$$\sum_{j} \sum_{b} \sum_{s \neq b} x_{i,j,s,b} Demand_{j,b} \leq D_s \qquad \forall s \tag{5}$$

$$\widetilde{Cr}\{\sum_{i} \sum_{j} \sum_{b} \sum_{s \neq b} x_{i,j,s,b} Demand_{j,b} \leq \varphi\} \geq \alpha \tag{6}$$

$$x_{i,j}\text{و}Z_i\text{و}x_{i,j,s,b} \in \{0,1\} \tag{7}$$

In this model, the primary objective is minimization of all intra-hub transformations in the chain. The constraint number 1 guarantees that the tie *j* can be transferred to hub *i*, in case when the hub *i* is formed and in other words if $Z_i = 1$, therefore *i* may belong to *j*. In the constraint number 2, if at least one attribution of non-hub points like *j* belongs to *i*, $\sum_j x_{i,j}$ then we can consider this capable of becoming a hub, which means $Z_i = 1$ or $Z_i = 0$. The constraint number 3 guarantees that the transformation between the two hubs *i* and *s* for the demand *j* and *b* is possible when *j* belongs to *i* and *b* belongs to *s*. The constraint 4 and 5 also guarantee that while this transformation happens, the capacities of the points of the hubs *i* and *s* are not complied with. The constraint number 6 also specifies that there is an amount of φ which is maximum for such transformations in credibility function and this amount must decrease as much as possible and also it must be higher than the minimum amount of α. In better words, the credibility function tends to enhance the amount of existing conflicts in different demands moving and between the alpha must go higher than an expected amount, Eq. (1) and Eq. (2) specify the relationships of this function in two general and specific modes for this issue. The constraint number 7 also specifies the kind of the variables in this question.

The credibility function is generally defined as follows:

$$\widetilde{Cr}\{\xi \leq r\} = 0.5(Sup_{x \in R}\mu\big(x, \tilde{\theta}\big) + Sup_{x \leq r}\mu\big(x, \tilde{\theta}\big) - Sup_{x > r}\mu\big(x, \tilde{\theta}\big) \tag{8}$$

On this basis, considering the amount$\alpha \in (0,1)$, the main objective of the issue can be stated as follows:

$$\min\{\varphi | \widetilde{Cr}\{\sum_{i} \sum_{j} \sum_{b} \sum_{s \neq b} x_{i,j,s,b} Demand_{j,b} \leq \varphi\} \geq \alpha \tag{9}$$

Therefore we have:

$$min \varphi \tag{10}$$

subject to

$$\widetilde{Cr}\{\sum_{i} \sum_{j} \sum_{b} \sum_{s \neq b} x_{i,j,s,b} Demand_{j,b} \leq \varphi \tag{11}$$

4. The solution

To study the behavior of the suggested algorithm in a chain some second-step elements (distributers) of a three level chain was reviewed. The proposed method specifies which way each distributer in the chain uses to manage its inventory. Note that as evident in the elements of the model and on the basis of distribution and the supply chain it can be stated that the transfers have been executed in a level which is between the hubs and the distributors. In other words, all transfers are in the level of distributors, some of which are hubs and some are only the points to offer services to the customers and is excused in the hub viewpoint. In this part the way to implement the simulation algorithm is explained for the issue. The algorithm starts with a primary answer which is generated randomly and ends with an ending condition. The ending condition for the algorithm is to perform 100 continuous repetition of the algorithm. Table 4 demonstrates the results of our survey for single distributing mode.

Table 4
Ranking the order models

method	cost	Difference with the previous rating	difference with the best	difference with the worst
SA	451792872	1	0	0.28576
LTC	475103765	0.04906	-0.051596416	0.2488
POQ	497376872	0.04478	-0.100895793	0.21358
WW	508679255	0.02222	-0.125912529	0.19571
SM	591295445	0.13972	-0.308775507	0.06508
LFL	606198552	0.02458	-0.341762098	0.04152
LUC	632457596.9	0.04152	-0.399883965	0

As can be seen in Table 4, the proposed simulated annealing method (SA) performs better than other seven methods in terms of cost. The 4th column in Table 4 shows the percentage of the difference of each method compared with the other methods (in terms of rank). As an example, the percentile difference for the method, the total cost, is calculated as follows:

$$\frac{Cost_{LTC} - Cost_{SA}}{Cost_{LTC}} = \frac{475103765 - 451792872}{475103765} = 0.049064846$$

Reviewing the numbers of the fourth column, it is clarified that the most difference is between the two continuous ranks related to the percentile difference of the method, the total cost, compared with the suggested algorithm.

The fifth column of this table shows the percentile difference of the cost achieved from every method compared with the best way or the proposed method. As an instance for the criteria, the economical number is calculated as follows:

$$\frac{Cost_{SA} - Cost_{POQ}}{Cost_{SA}} = \frac{451792872 - 497376872}{451792872} = -0.100895793$$

The numbers in this column are in subtractive mode, in other words, by increasing the ranking of the presented methods the gap with the SA are widen. Also note that the negative digits do not show the error percentage and show the difference between models and the algorithms only. In the sixth column of this table the percentile difference has been shown through the worst way or as it is called the unit cost way. As an example this principle has been calculated as following for Wagner and Within method:

$$\frac{Cost_{LUC} - Cost_{WW}}{Cost_{LUC}} = \frac{632457596.9 - 508679255}{632457596.9} = 0.195710104$$

According to Fig. 2 SA has presented the least and the unit cost method has offered the most cost.

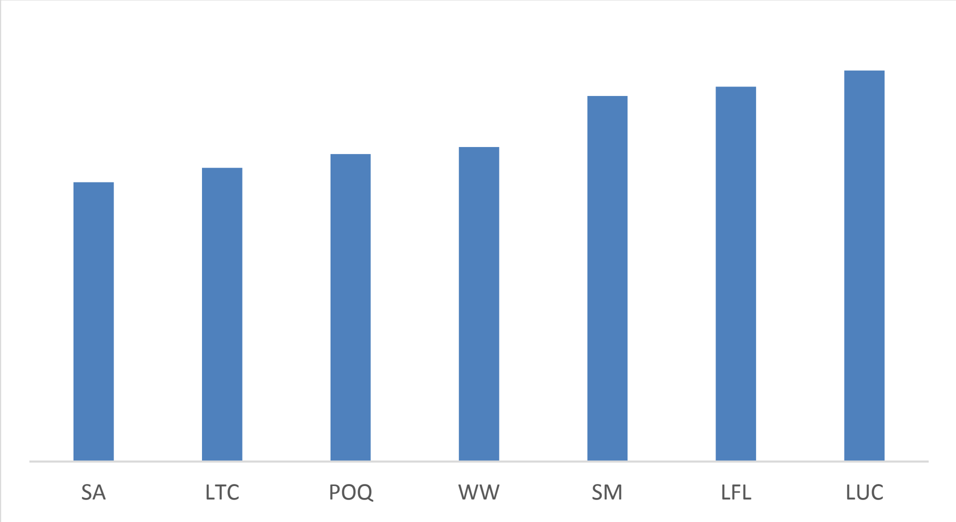

Fig. 2. The amount of costs between different methods

4.1 In supply chain mode

Since the proposed method of this paper is formulated as mixed integer programming, it is necessary to use the meta-heuristic method introduced to find near optimal solutions. In this survey, we use Matlab R 2013a. After optimization, the evaluation principle for each sample questions is as follows:

- For the issues of 30 demand points, the equality of the answers has been achieved using the two mentioned algorithm for all 15 tested samples.
- For the issues of 60 demand points, among 15 solved questions, twelve of them are binding. For the rest of the questions the lower bounds have been achieved via critical way method and the evaluation principle is the deviation from this amount.

On the one hand, the data of this research has been created and analyzed on the basis of random digit creation. Also the summary of the results and figures of comparing the function of simulating algorithm for all questions are given in Table 5 and note that the costs are at million. In addition Fig. 3 demonstrates the comparison between the best answers and the worst answers and the average of the result of each method in 30-distributor mode and 60-distributor mode has been presented:

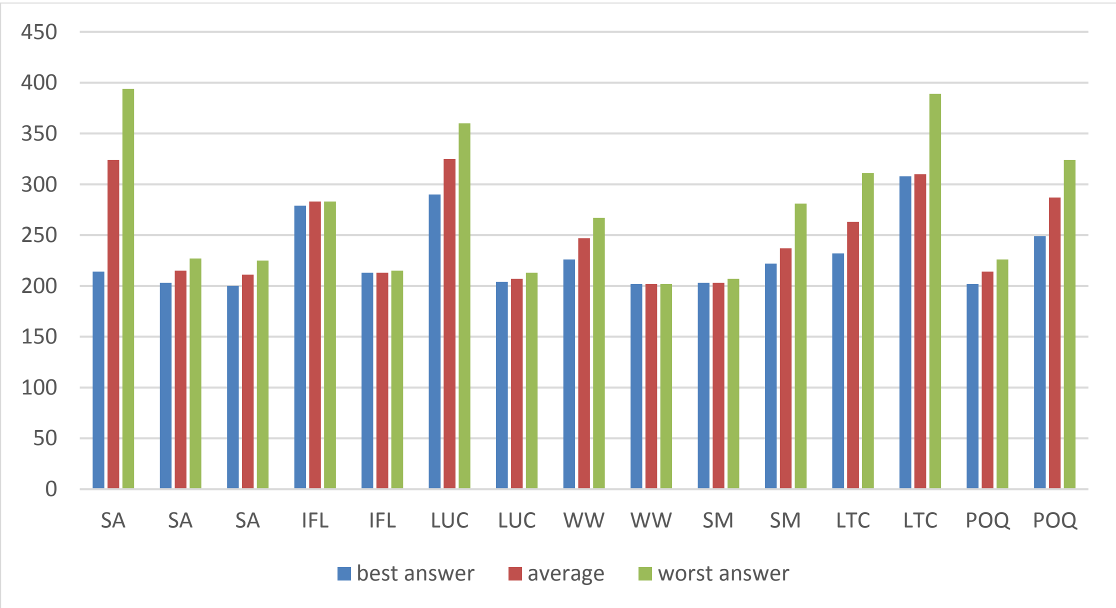

Fig. 3. The comparison chart for 30 distributors

Table 5
Comparing the models in supply chain

Question size			Simulation algorithm			Inventory policy type
Distributor numbers	demander	Hub	best answer	average	worst	
30 distributor	35	3	214	324	394	SA
	37	3	203	215	227	
	39	3	200	211	225	
	32	3	279	283	283	LFL
	33	3	213	213	215	
	34	3	290	325	360	LUC
	43	5	204	207	213	
	44	5	226	247	267	WW
	45	5	202	202	202	
	43	5	203	203	207	SM
	49	5	222	237	281	
	42	5	232	263	311	LTC
	66	8	308	310	389	
	62	8	202	214	226	POQ
	63	8	249	287	324	
60 distributor	63	5	223	322	363	SA
	64	5	277	280	382	
	67	5	223	223	225	
	62	5	345	346	383	LFL
	69	5	322	322	327	
	63	5	213	218	219	LUC
	65	8	201	234	255	
	62	8	291	296	303	WW
	61	8	380	392	392	
	81	10	331	333	393	SM
	84	10	224	227	229	
	85	10	345	364	395	LTC
	86	10	275	365	392	
	87	10	264	291	297	POQ
	82	10	227	252	345	

According to Fig. 3 and Fig. 4, the best answers in sample issues have been the same for different algorithms, therefore, the suggested algorithm has a usual function compared with other competitors in the chain.

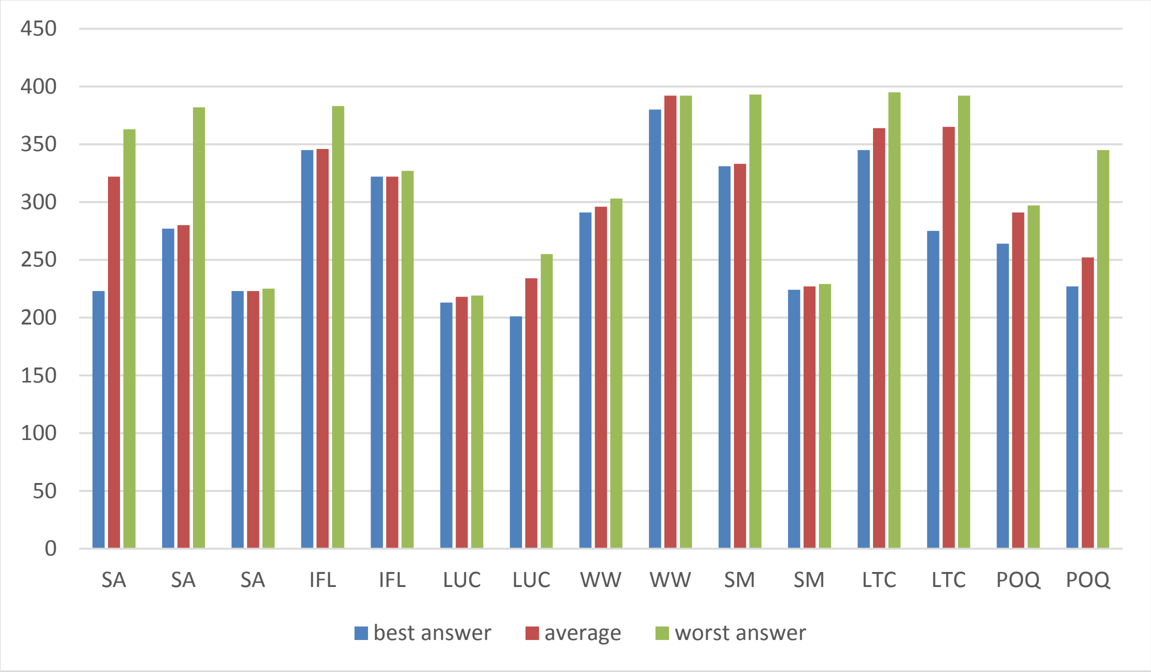

Fig. 4. The comparison chart for 60 distributors

5. Conclusion

The main objective in managing the supply chain is to make a trustworthy flow in transferring the material and the services from the beginning to the end of the supply chain, keeping the inventory in order to increase the level of services and decreasing the production costs. The inventories have to be managed to minimize the costs and to optimize the other indexes such as ensuring delivery system in supply chain. Therefore, in this research the models of periodical orders including POQ, LTC, LTC, LUC, SM, WW and FL have been considered using the suggested simulation algorithm on the basis of minimizing the total inventory costs and improving the target function in a supply chain aiming to create a hub. Hence, to review the presented methods there was a three-level supply chain presented by 30 and 60 distributors and the results for each model of periodical order have been compared with each other using the simulation algorithm. In this comparison as it was obvious the best answers in sample issues perform the same for different algorithms. Although most modern ways have been offered such as the ways presented by Samak-Kulkarni and Rajhans (2013) the proposed model of this paper has been able to do better compared with other similar ways of inventory management.

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