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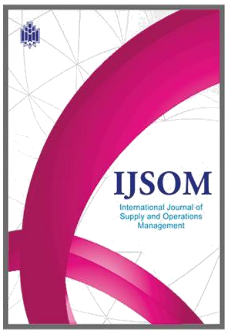

A Mathematical Approach to Ordering Policy Selection for Cold Items in a Warehouse with Different Operational Constraints

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Abstract

According to the importance of keeping temperature-dependent products, the present study investigated the inventory control of cold products. In this study, a warehouse with limited space and ambient temperature is assumed. Based on the assumptions of the problem, the best ordering system for cold products should be selected from the two fixed order size and periodic review systems by formulating a mixed integer nonlinear programming model. The objective of the model is to minimize the sum of costs, including adjusting the temperature of the products and the cost of producing fluoride gas produced by keeping them in the refrigerator and for both types of ordering systems, taking into account different constraints consisting of warehouse space, available budget, the storage temperature of the products in the warehouse and the maximum number of cold products that can follow any ordering system. Finally, by solving the model, the type of ordering system for each product, the ordering system characteristics and their storage temperature are obtained. After solving the model, sensitivity analysis is performed on different parameters including available space for holding the products at the warehouse, available budget, the minimum number of the products that can follow a specific ordering system and shortage cost and the results are discussed.

Keywords: Inventory control of cold products; Periodic review system; Fixed order size system; Sensitivity analysis.

1. Introduction

Choosing an ordering system for cold products is a very crucial issue in inventory planning and control. Generally, there are two types of ordering policies or systems to control and manage inventory levels: Fixed Order Size System and Periodic Review System. Fixed Order Size System is a kind of inventory system in which ordering is issued exactly at the moment that the inventory level reaches r at fixed or variable time intervals. Periodic Review System (R, T) is a sort of ordering system in which ordering always takes place at specific T time intervals. Since perishable products (i.e. cold products) such as dairy products, frozen fish, meat and chicken are highly sensitive to temperature, they should be kept under special temperature conditions in the warehouse, otherwise their quality suffers over time and eventually they spoil. Apart from the excessive costs that the total spoilage of the products or the impairment of their quality would bring about, it would also endanger individuals' life as a result of poisoning. Among the factors which can increase the risk of cold product spoilage are:

- The limited shelf life of the products and the need for special control and maintenance of these products,
- The possibility of not receiving, distributing and delivering orders on time,
- Failure to select the appropriate ordering system and determine the appropriate storage temperature for them,

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Also, because of the special nature of some cold and perishable items, they cannot be recycled and their waste material can lead to irreparable damage to the environment. Consequently, in order to prevent the damage and to minimize costs, appropriate decisions such as choosing the best system for ordering and holding temperature for each type of the products should be made.

In this research, based on the assumptions of the problem, the best ordering system for cold products is chosen between the two inventory systems of Fixed Order Size System and Periodic Review System by formulating a Mixed-Integer Nonlinear Programming (MINLP) model. The main contributions of the present research can be listed as follows:

- Cold products will lose their quality over time, thus temperature adjustment in the warehouse is very important. In this research the cost of temperature adjustment is considered as a linear function and it is minimized.
- Refrigeration systems produce large amounts of greenhouse gases that have a high global warming potential with a very long lifetime in the atmosphere. Regular and catastrophic leakage of these gases from cold supply chain constitutes a significant component of their global warming impact, therefore the fluoride gas produced when keeping products in the refrigerator is minimized in the current research to prevent damage to the environment.
- One of the most important factors in preventing cold products from spoiling and in maintaining their quality is temperature. Therefore, standard storage temperature of the perishable products in the warehouse is obtained in the current research.
- The most appropriate ordering policy (fixed order size or periodic review) for the products is obtained in this research in order to reduce the effect of factors which can increase the risk of spoilage for cold products.
- ordering system features for all of the products, such as ordering quantity of cold products for fixed order size inventory system, ordering period of cold products for periodic review inventory system and reordering point of cold products for fixed order size and periodic review inventory system, are obtained.

To show the application of the present research, for example, the frozen fish sales and storage department in a chain store can be considered. If the fish are not kept at the right temperature in the refrigerator, they will quickly lose their quality and spoil and it will cause financial damage to the store. Also, if the product is not ordered on time and of the required amount, it can cause product shortage and stores will lose their customers. By applying the mathematical model and solving that for the store, determining the appropriate temperature for keeping the fish and taking the proper ordering policy all negative consequences can be prevented.

In this article, firstly, the literature related to the present research is reviewed. Then, in the second section, the problem is stated and in section 3, the specified model is presented. In section 4 the computational results are presented. Ultimately, some conclusions are drawn and several suggestions for future research are made.

2. Literature review

The issue of the ordering policies for the cold and perishable products has been attended in recent years by various researchers, some of which are as follows:

Redmond et al. (2004) studied the influence of cooling and freezing on the quality of green peas and carrots and stocked the products in the short and long run. In the short term, they performed three processes of chilling, freezing-chilling and freezing on the products and examined the characteristics such as color, stability and firmness, taste, durability. Zhang et al. (2003) showed the issue of locating centralized distribution warehouses for cold products and allocating central warehouses for the storage of cold goods to plants. A mathematical model was proposed, whose objective minimized the total operational costs such as the depots cost, the transportation cost, keeping products quality and penalty. Tabu Search method was used for optimizing the considered supply chain for cold products. Zanoni and Zavanella (2007) proposed a MILP model for the transportation problem of the chilled goods, from an origin (the seller) to a destination and the goal of the problem was to minimize the inventory cost and transportation cost. The numerous heuristic algorithms, six methods, were developed to solve it and finally, after solving some numerical examples and solving them with the employed algorithms, it was proved that the best solution algorithm was BestPer algorithm. Ferguson et al. (2007) presented an EOQ model and keeping cost was considered a nonlinear function. In fact, an estimation for the optimal ordering quantity of deteriorating products was provided. Also the cost parameters were estimated through a regression approach and a markdown policy for near-expiration products was considered. James et al. (2006) reviewed the modeling of cold and frozen food transportation and cooling systems, which were used to keep foods cold and frozen at the right temperature and maintain their health. The purpose of the modeling in this area was to design and optimize food refrigeration systems, and most reviews focused on the cooling process (e.g. freezing) that changes the temperature of the foods. Blackburn and Scudder (2009) examined the strategies of supply chain design for certain types of deteriorating goods, (i.e. cold products). Given the lost value of goods rate over the time in the considered supply chain, an appropriate model was developed that its objective was minimizing lost value of products in the considered supply chain. Rong et al. (2011) studied a MIP model for the production and distribution planning of cold foods, with considering the quality of products that were temperature dependent. They also provided a relationship between food quality degradation and temperature mathematically. The considered purpose for their distribution and production problem was to determine transportation and storage temperatures, production values and delivery routes for the products and the costs such as storage and cooling costs were minimized, and the retailers requirements for demand and quality were fulfilled. Zanoni and Zavanella (2012) demonstrated the cold food supply chain and the impact of cold food storage temperature and time on the quality of the perishable products, costs, and sustainability of the cold supply chain. A model was presented in which the relationship between the rate of quality degradation for cold products and the required energy to preserve them was shown. Also, the relationship between temperature and the quality of the product was shown by using formulas for the quality level of the products, temperature-dependent coefficient and the quality degradation of the products. Zhao et al. (2012) have proposed fixed ordering inventory systems with limited resource for different state of items. An algorithm was used to obtain the optimal *r and Q* in the single-product system so that the average system costs were minimized. An optimization problem was also developed to find the optimal *(r,Q)* in the multi-items system for all goods, to minimize the average costs. Tripathi (2014) investigated an inventory model for deteriorating products with considering production rate and demand rate. The proposed problem was solved by Mathematica 7 software and also sensitivity analysis was used for investigating influence of changing the different parameters of the model. Saif and Elhedhli (2016) proposed a MIP model for designing the cold supply chain with two goals of minimizing sum of the costs including capacity cost, transportation cost, and inventory costs and the environmental effect. In their research, the demand parameter was considered as a known distribution. Also inventory is managed using a known policy. A hybrid simulation optimization algorithm was proposed for solving the problem. Lagrangian decomposition was used to compose the proposed model into an IP sub-problem. Sandra Rajan and Uthayakumar (2015) demonstrated a kind of inventory model with two warehouses with considering authorized delay in payment period. The goal of the presented model was minimizing retailer costs and obtaining optimal policy for replenishment. Fattahi et al. (2015) investigated a multi-items inventory model with fixed order size policy and two objective is considered for the proposed model. The first objective function was minimizing sum of the costs and the second objective function was maximizing service level. The considered inventory system was periodic review. The purpose of their work was to obtain the optimal value of ordering quantity and reordering point. Several Pareto-based meta-heuristic algorithms for example, multi-objective vibration damping optimization and multi-objective imperialist competitive algorithm were used for solving the proposed model. Gharaei et al. (2016) designed and optimized an inventory model with considering a four-echelon supply chain with a supplier, a producer, a wholesaler and multiple retailers. In their research, the total inventory cost was minimized while the stochastic constraints were satisfied. An algorithm was proposed for solving the mathematical model. Hsiao et al. (2017)examined a cold chain food distribution planning problem for generating a distribution plan to eliminate customer necessities for different cold products with pre-determined quality levels at the lowest cost. The quality level was determined with due attention to the estimated shelf life, which varies by food type and storage temperature. The investigated model minimized the total cost such as delivery person, the total fuel of a travelling vehicle and an idling vehicle, temperature setting, the total carbon emission, quality substitution and shortage. Tao et al. (2017) demonstrated a single level, periodic review inventory system with both regular and expediting modes were available in a plant. The applied ordering policy was (*S, e)* that *S* was the inventory level for re-ordering and *e* was a specified inventory level and then a simulation approach was used for solving the problem. Rafie-Majd et al. (2018) modeled a three level supply chain, using an integrated inventory location routing problem. Lagrangian Relaxation (LR) Method was used for solving the model and an algorithm was presented to make feasible the result of the LR algorithm. Saha and Chakrabarti (2018) studied a two-level supply chain model for corrupting products with considering a retailer and a manufacturer and sensitivity analysis was applied for studying influence of changing the various parameters of the model. Mokhtari et al. (2020) proposed a production-inventory planning model for growing and deteriorating items with the aim of obtaining optimal ordering quantity for mentioned products. Pervin et al. (2015) investigated the optimal retailer's replenishment decisions for deteriorating items under a trade credit policy to reflect more realistic situations within an economic product quantity framework and an inventory model when the supplier offers the retailer a credit period to settle the account, if the retailer orders a large quantity, was analysed. Pervin et al. (2018) developed a deterministic inventory control model with deterioration and the deterioration rate followed stochastic deterioration, especially Weibull distribution deterioration. Also the optimal retailer's replenishment decisions for deteriorating items including time-dependent demand for demonstrating more practical circumstances within economic-order quantity frameworks, were investigated. Pervin and Roy (2017) proposed an inventory model for deteriorating items with stock dependent demand rate so that Shortages were allowed to their model and when stock on hand was zero, then the retailer offered a price discount to customers who are willing to back-order their demands. Pervin and Roy (2018) studied an integrated vendor-buyer model for deteriorating items so that it was assumed that the deterioration followed a constant rate with respect to time and the vendor allowed a certain credit period to buyer in order to promote the market competition. Pervin (2019) demonstrated a multi-item inventory model for deteriorating items and the model was formed on the basis of a two-level supply chain policy. The deterioration rate was considered as constant and the demand of any item was also dependent on its selling price. Barman et al. (2020) presented an Economic Production Quantity model for deteriorating items with time-dependent demand and shortages including partially back-ordered under a cloudy-fuzzy environment. Khan et al. (2020) formulated, under both cases of advance payment (full or partial), an inventory model for deteriorating products where shortages were allowed and demand function was considered as price and stock dependent. Khan et al. (2020) presented a two-storage inventory model with advance payment under three different situations according to different possibilities of starting times of deterioration in two warehouses and demand depended upon the selling price wherein shortages were considered partially with fixed backlogging rate. Das et al. (2020) proposed an inventory model of non-instantaneous deteriorating items with the demand dependent on the selling price of the product and two different preservation rates were considered and also Shortages were allowed partially with two different backlogging rates. Shaikh et al. (2019) investigated a two warehouse inventory model with advanced payment, partial backlogged shortages and different variants of particle swarm optimization techniques (viz. PSO-CO, WQPSO and GQPSO) were developed to solve the problem of the proposed inventory model. Khan et al. (2019) developed a two-warehouse inventory model for deteriorating items with advanced payment scheme and Shortages were allowed with a constant partial backlogging rate and Demand of the product was dependent on selling price. Shaikh et al. (2019) investigated two different inventory models, namely (a) inventory model for zero-ending case and (b) inventory model for shortages case and the demand for both models was considered as price and stock dependent, whereas shortages were partially backlogged at a rate with the length of the waiting time to the arrivals of the next lot. Khan et al. (2019) presented two supply chain models by assuming the demand of the product to be dependent on price and also, shortages were considered and these depended on the customer waiting time.

To sum up, the following table summarizes the most prominent mentioned researches:

Table 1. The most prominent mentioned researches

Authors	supply chain		ordering system			mathematical model		constraint	parameters		solving method	
	single level	multi-level	fixed order size	periodic review	EOQ	single objective	multi objective		deterministic	stochastic	exact	meta heuristic
Zhang et al.		*				*		*	*			*
Zanoni & Zavanella						*		*	*			*
Ferguson et al.					*	*						
Blackburn & Scudder					*	*			*		*	
Rong et al.		*				*		*	*		*	
Zanoni & Zavanella		*				*			*			
Zhao et al.		*	*			*			*	*	*	
Saif & Elhedehli		*	*			*		*	*	*	*	
Fattahi et al.	*		*				*	*	*	*		*
Gharaei et al.		*				*		*	*	*	*	
Hsiao et.al.		*		*		*		*	*	*	*	
Tao et al.	*			*		*		*	*	*	*	
Rafie-Majd et al.		*	*			*		*	*	*	*	*
current research	*		*	*		*		*	*		*	

3. Problem definition

A warehouse with a limited available space and a specific ambient temperature is assumed. There are cold-perishable products that are temperature-dependent and must be kept at low temperature in the refrigerator. The refrigerator is settled in the warehouse. The best ordering system for each type of cold goods should be selected from the two prevalent ordering systems including fixed order size and periodic review, taking into account the following assumptions:

- The space of the warehouse is limited.

- The accessible budget to provide the cold and deteriorating products is limited.
- The maximum number of the products that can follow a specific ordering system is N.
- The storage temperature of the products has a lower bound and an upper bound.

The objective is minimizing sum of the total holding cost, ordering cost, shortage cost, modifying temperature cost and fluoride gas production are minimized for both of ordering systems. In this problem, the type of ordering system assigned to every product, the point of ordering for any product and every type of ordering system, the ordering period of each product in the periodic review system, as well as, the ordering quantity of each product, and their storage temperature in the warehouse are obtained.

4. Mathematical modelling

In this section, mathematical model of the problem that was described in the previous section, has been proposed. The indices are shown in Table 1, the parameters are shown in table 2, and the decision variables are shown in table 3.

Table 2. Indices

Index	definition
j	Index for cold products (*j*=1,…,n)

Table 3. Parameters

parameter	definition
h_j	Holding cost of one unit of product *j* per unit of time
π_j	Shortage cost per unit of product *j*
ec_j	reducing temperature cost per unit of product *j*
fc_j	Fixed cost for setting of the warehouse for product *j*
c_j	Shopping cost per unit of product *j*
A_j	Ordering cost of product *j*
D_j	Demand quantity of product j over a period of time
ss_j	Safety inventory of product *j*
$\bar{b}(r_j)$	Average shortage of product *j* for fixed order size ordering system
$\bar{b}(R_j)$	Average shortage of product *j* for periodic review ordering system
μ_{Lj}	Average demand of product *j* in fixed order size ordering system at lead time L
$\mu_{L+T,j}$	Average demand of product *j* in periodic review ordering system at lead time $L+T$
f_j	The space that product j occupies in the warehouse
$eHFC_j$	The amount of fluoride gas was produced because of holding one unit of product *j* in the refrigerator
U_j	Upper bound temperature for holding product *j* in the warehouse
L_j	lower bound temperature for holding product *j* in the warehouse
B	Available budget that is a random variable with normal distribution, mean of E(B) and variance of Var(B).
F	Available space for holding the products at the warehouse budget that is a random variable with normal distribution, mean of E(F) and variance of Var(F).
N	The minimum number of the products that can follow a specific ordering system.
T_e	Ambient temperature

Table 4. Decision variables

decision variable	definition
Q_j	Ordering quantity of product *j*
r_j	Reordering point of product *j* in fixed order size ordering system
R_j	Reordering point of product *j* in periodic review ordering system
T_j	Ordering period of product *j*
$\acute{T}_j$	Holding temperature per unit of product *j* in the warehouse
Y_j	1, if ordering system of product *j* is fixed order size, 0 otherwise

The mathematical model of the problem has been brought in the following.

$$minz=\sum_{j=1}^{n}Y_j\,(h_j\left(\frac{Q_j}{2}+r_j-\mu_{Lj}\right)+\frac{A_jD_j}{Q_j}+\pi_j\frac{D_j}{Q_j}\bar{b}(r_j))+\sum_{j=1}^{n}[(1-Y_j)(h_j\left(\frac{D_jT_j}{2}+R_j-\mu_{L+T,j}\right)+\frac{A_j}{T_j}+\frac{\pi_j}{T_j}\bar{b}(R_j))]$$
$$+\sum_{j=1}^{n}[(fc_j+ec_j(T_e-\acute{T}_j))\times Y_j\times\frac{1}{T_j}+(1-Y_j)\frac{D_j}{Q_j}(fc_j+ec_j(T_e-\acute{T}_j)]+\sum_{j=1}^{n}[(r_j-\mu_{Lj}$$
$$+\frac{Q_j}{2})c_jY_jeHFC_j+(1-Y_j)c_j(R_j-\mu_{L+T,j}+\frac{D_jT_j}{2})eHFC_j] \tag{1}$$

s.t:

$$\sum_{j=1}^{n}(Y_j(r_j+Q_j)f_j+(1-Y_j)R_jf_j)\leq F \tag{2}$$

$$\sum_{j=1}^{n}Y_j\geq N \tag{3}$$

$$\sum_{j=1}^{n}((r_j-\mu_{Lj}+\frac{Q_j}{2})c_jY_j+(1-Y_j)c_j(R_j-\mu_{L+T,j}+\frac{D_jT_j}{2}))\leq B \tag{4}$$

$$L_j\leq\acute{T}_j\leq U_j \qquad \forall j=1\dots n \tag{5}$$

$$Y_j\epsilon\{0,1\} \qquad \forall j=1\dots n \tag{6}$$

$$r_j,Q_j,R_j,T_j\geq 0 \qquad \forall j=1\dots n \tag{7}$$

$$\acute{T}_j: free \qquad \forall j=1\dots n \tag{8}$$

The objective function (1) minimizes holding, ordering, shortage and temperature adjustment cost, emission fluoride gas because of holding cold products in the refrigerator. Constraint in Eq. (2) states that the total occupied space by all of the products should not exceed from the available space for holding all of the products at the warehouse. Constraint in Eq. (3) enforces that at least *N* products can follow fixed order size ordering system. Constraint (4) exposes that sum of the shopping costs of the cold products have to be less than the available budget. Constraint (5) states that the holding temperature of products in the warehouse should be between a lower bound and upper bound. Constraints (6), (7) and (8) also show the sign of decision variables.

5. Numerical experiment and sensitive analysis

A chain store with four types of products is assumed. The values of the costs and other parameters are as follows:

Table 5. Parameters for numerical example

products / parameters	1	2	3	4
h_j	120	200	140	190
π_j	60	75	55	65
ec_j	45	60	50	55
fc_j	1500	1000	1300	1400
c_j	45	75	55	65
A_j	300	450	350	400
D_j	10	8	12	15
μ_{Lj}	5	5	5	5
$\mu_{L+T,j}$	10	10	10	10
f_j	50	60	55	65
$eHFC_j$	10	15	14	12
U_j	4	4	4	4
L_j	-5	-5	-5	-5
B	7000	7000	7000	7000
F	20000	20000	20000	20000
N	2	2	2	2
T_e	25	25	25	25

The demand distribution for fixed order size ordering system is uniform in the interval (0,10) and for periodic review ordering system is uniform in the interval (0,20). Therefore, the shortage value for both types of ordering system is obtained by integrating the density function with the demand over the specified interval. After solving the nonlinear mixed integer programming model using Gams24.8.2 software, the objective function value was 42115.116 units. The value of the decision variables is as follows:

Table 6. Value of decision variables for numerical example

product / decision variable	1	2	3	4
Ordering system	Fixed order size	Fixed order size	Periodic review	Periodic review
Ordering quantity	3.627	2.562	-	_
Point of reordering	5	5	10	10
Holding temperature	4	4	4	4
Ordering period	-	-	0.167	0.167

Sensitivity analysis is one of the most important topics in operations research that identifies the impression of the parameters on the optimal solution and examines the optimal value of the objective function and the optimal solution of the problem under the influence of important parameters. In this method, at any time, the effect of modifying one parameter is examined when the other parameters are supposed to be constant. If the optimal solution is highly sensitive to changes of a parameter, the value is revised and then the model is resolved. It is crucial to find an answer that is less sensitive to parameter change.

According to the parameters value of the numerical example and each table, sensitivity analysis is performed on F (available space for holding the products at the warehouse), B (available budget), N (the minimum number of the products that can follow a specific ordering system) and π_j (shortage cost of product j).

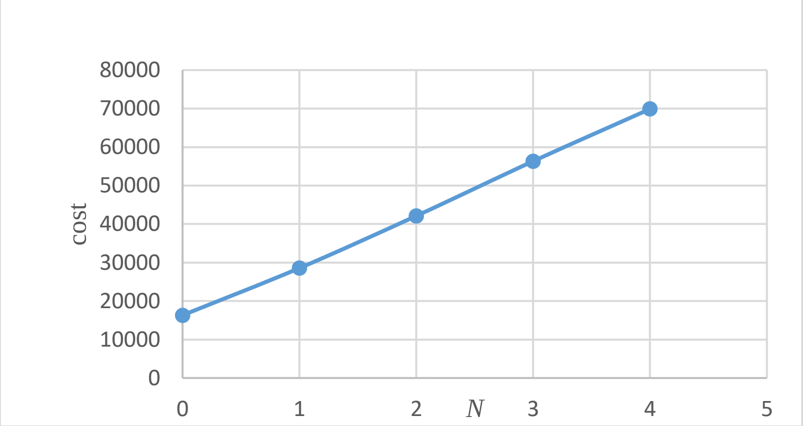

Figure 1. Sensitivity analysis on N parameter (the minimum number of the products that can follow a specific ordering system.)

Table 7. Sensitivity analysis on N parameter

parameters (unit)	cost value (unit)
N=0,B=7000,F=20000	16305.756
N=1,B=7000,F=20000	28552.581
N=2,B=7000,F=20000	42115.116
N=3,B=7000,F=20000	56326.336
N=4,B=7000,F=20000	69888.871

Table (7) shows the results of the sensitivity analysis on N parameter. According to fig (1), the higher the N parameter, the higher the objective function value. That is, by increasing the minimum number of products that follow fixed order size ordering system and keeping the other parameters constant, the total cost of the system increases.

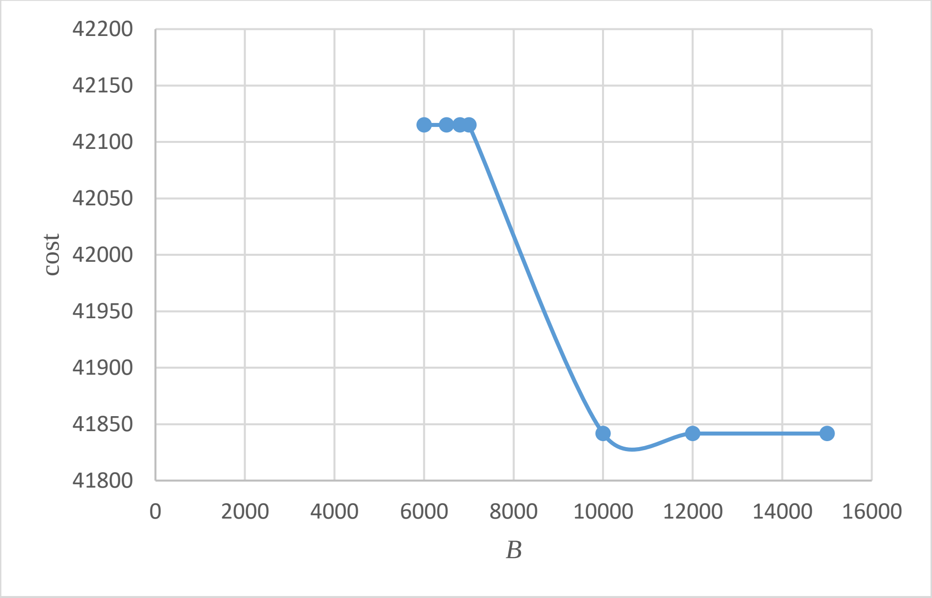

Figure 2. Sensitivity analysis on *B* parameter (available budget)

Table 8. Sensitivity analysis on *B* parameter

parameters (unit)	cost value (unit)
N=2,*B*=6000,*F*=20000	42115.116
N=2,*B*=6500,*F*=20000	42115.116
N=2,*B*=6800,*F*=20000	42115.116
N=2,*B*=7000,*F*=20000	42115.116
N=2,*B*=10000,*F*=20000	41841.666
N=2,*B*=12000,*F*=20000	41841.666
N=2,*B*=15000,*F*=20000	41841.666

Clearly, the greater the budget available to purchase products, the lower the cost of an inventory system such as the cost of purchasing. This is also obvious in the figure (2). Table (8) indicates the results of the sensitivity analysis on *B* parameter. Fig (2) declares that the higher *B* parameter, the lower the objective function value, it means that by increasing the available budget and keeping the other parameters constant, the total cost decreases.

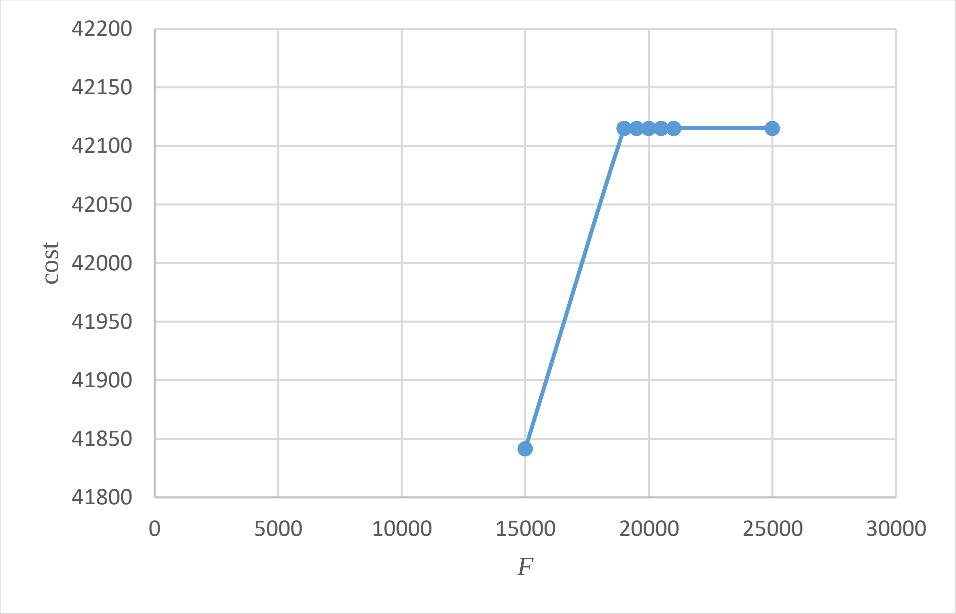

Figure 3. Sensitivity analysis on *F* parameter (available space for holding the products at the warehouse.)

Table 9. Sensitivity analysis on *F* parameter

parameters (unit)	cost value (unit)
N=2,B=7000,F=15000	41841.666
N=2,B=7000,F=19000	42115.116
N=2,B=7000,F=19500	42115.116
N=2,B=7000,F=20000	42115.116
N=2,B=7000,F=20500	42115.116
N=2,B=7000,F=21000	42115.116
N=2,B=7000,F=25000	42115.116

The more space available for products in a warehouse, the more products can be stored in it, thus the cost of the inventory system such as holding cost, will increase. Table (9) exposes the results of the sensitivity analysis on *F* parameter. Fig (3) states that the higher *F* parameter, the higher the objective function value, it means that by increasing the available space of the warehouse and keeping the other parameters constant, the total cost of the whole system increases. The second column of the tables shows the cost value according to the parameter values and using the Gams 24.8.2 software.

Table 10: Sensitivity analysis on the shortage cost

parameters (unit)	cost value (unit)
$\pi_1 = 38.4\ \pi_2 = 48\ \pi_3 = 35.2\ \pi_4 = 41.6$	41284.239
$\pi_1 = 48\ \pi_2 = 60\ \pi_3 = 44\ \pi_4 = 52$	41654.293
$\pi_1 = 60\ \pi_2 = 75\ \pi_3 = 55\ \pi_4 = 65$	42115.116
$\pi_1 = 72\ \pi_2 = 90\ \pi_3 = 66\ \pi_4 = 78$	42574.103
$\pi_1 = 86.4\ \pi_2 = 108\ \pi_3 = 79.2\ \pi_4 = 93.6$	43122.599

Table (10) shows the results of sensitivity analysis on the shortage cost of the products. According to Table (10), by increasing the shortage cost of products, the total cost of the whole system increases.

6. Conclusion

Since determining the ordering system for different products is an important issue in inventory planning and control, the present study addresses this issue for temperature-dependent and perishable products. The main contribution of this paper against other researches is minimizing the cost of temperature adjustment of the perishable products and fluoride gas was produced by holding products in the refrigerator to prevent damage to the environment, obtaining storage temperature of the perishable products in the warehouse, choosing the most appropriate ordering policy for the products, obtaining ordering system features for all of the products, such as ordering quantity and ordering period. The mentioned mathematical model has many applications, for example the meat sales department of a chain store, by solving this model it can obtain the exact temperature, ordering system and its features for its perishable products and it prevented the extra costs and made them corrupt. Finally, Sensitivity analysis has been performed on the three parameters to evaluate the impact of system parameters. The results of the sensitivity analysis are as following table.

Table 11. Result of the sensitivity analysis

Parameter	Result of the sensitivity analysis on the parameter
N	The higher the *N* parameter, the higher the total cost value.
B	The higher *B* parameter, the lower the total cost value.
F	The higher *F* parameter, the higher the total cost value.
π_j	The higher π_j parameter, the higher the total cost value.

From the performed sensitivity analysis, the following findings can be proposed to the decision maker:

- By increasing the available space of the warehouse, the total cost of the whole system increases. For solving this problem, the decision maker can consider the available space of the warehouse in proportion to the number of the products, neither less nor more.
- By increasing the minimum number of products that follow fixed order size ordering system the total cost of the system increases. For solving this problem, with due attention to accuracy of fixed order size system, decision maker can consider this inventory system only for very important or strategic products.

- By increasing the available budget, the total cost of the system decreases. Therefore Decision maker should increase the available budget for purchasing the products.
- By increasing the shortage cost of the products, the total cost of the system increases. Decision maker should order the products on time and of the required amount. Also, the decision maker must make a comparison between the holding cost and the shortage cost. If the shortage cost is lower than the holding cost, he should prefer the shortage cost.

For the future research, the following items are suggested:

- Using meta-heuristic algorithms as an efficient solution methods
- Modeling the problem as a multi objective problem
- Considering some of the parameters of the problem as fuzzy parameters
- Considering other operational constraints
- Adding other factors such as humidity in the warehouse
- Considering some cases which are concern to reduce the environmental damage

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