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ORIGINAL PAPER

REPLENISHMENT POLICY FOR ENTROPIC ORDER QUANTITY (ENOQ) MODEL WITH TWO COMPONENT DEMAND AND PARTIAL BACK-LOGGING UNDER INFLATION

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ABSTRACT. **Background**: Replenishment policy for entropic order quantity model with two component demand and partial backlogging under inflation is an important subject in the stock management.

Methods: In this paper an inventory model for non-instantaneous deteriorating items with stock dependant consumption rate and partial back logged in addition the effect of inflection and time value of money on replacement policy with zero lead time consider was developed. Profit maximization model is formulated by considering the effects of partial backlogging under inflation with cash discounts. Further numerical example presented to evaluate the relative performance between the entropic order quantity and EOQ models separately. Numerical example is present to demonstrate the developed model and to illustrate the procedure. Lingo 13.0 version software used to derive optimal order quantity and total cost of inventory. Finally sensitivity analysis of the optimal solution with respect to different parameters of the system carried out.

Results and conclusions: The obtained inventory model is very useful in retail business. This model can extend to total backorder.

Key words: Entropic Order Quantity (EnOQ), two component demand, partial back-logging, inflation.

INTRODUCTION

It is focused on an area of emerging research: Replenishment policy for entropic order quantity model with two component demand and partial backlogging under inflation. Present stylized model by introducing entropy cost for analysing the given replenishment policy. In this paper we have developed an inventory model for non-instantaneous deteriorating items with stock dependant consumption rate and partial back logged in addition the effect of inflection and time value of money on replacement policy with zero lead time consider. Profit maximization model is formulated by considering the effects of partial backlogging under inflation with cash discounts. Further numerical example presented to evaluate the relative performance between the entropic order quantity and EOQ models separately. Numerical example is present to demonstrate the developed model and to illustrate the procedure. Lingo 13.0 version software used to derive optimal order quantity and total cost of inventory. Finally sensitivity analysis of the optimal solution with respect to different parameters of the system carried out. The model is very useful in retail business. This model can extend to total backorder.

It has been observed in supermarket that the demand rate usually influenced by that amount of stock-level that is the demand rate may go up or down with the on-hand stock level. The presence of Inventory has a motivational effect on the people around it. Vrat and Padmanabham [1990] (first developed an EOQ

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models under inflation for stock dependent consumption rate items.

Generally, goods in inventory do not always safeguard their physical characteristic because some items which are subject to risks like breakage, evaporation, obsolescence etc. It is important to control and maintain the inventories of deteriorating items for Modern Corporation. In recent years, Inventory problems for deteriorating items have been widely studied after Ghare and Schrader [1963]. They presented an economic order quantity (EOQ) model for an exponentially decaying inventory [Gahan 2017].

Furthermore, when the shortages occur, it is assumed that it is either backlogged or completely lost. But practically some customers are willing to wait for backorders and others would turn to buy from other sellers.

Researcher Wee [2001] developed inventory models with practical back orders. Goyal and Giri [2001] developed production inventory model with shortages partially backlogged. Wee [1995], developed a deterministic lot size Inventory model for deteriorating items with shortages and declining market. Jaber, Bonney and Rosen [2008] developed entropic order quantity (EnOQ) model for deteriorating items.

All the models mentioned above, the inflation and time value of money were not considered because of the belief that the inflation and time value of money would not influence the inventory policy to any significant degree. In the last several years most of the countries have suffered from large scale inflation and sharp decline in purchasing power of money. As a result while, determining the optimal inventory policy, the effect of inflation and time value of money cannot be ignored [Ahmed, Sultana, 2014].

The pioneer researcher Buzacott [1975] developed an EOQ model with inflation subject to different types of pricing policies. Vrat and Padmanabham [1990] develop an inventory model under a constant inflation rate for initial stock dependent consumption rate. Later, Chung, Tsu and Liang [2007], Wee and Law [2001] have investigated the effect of inflation time value of money and deterioration on Inventory models.

Table 1. Major characteristics of inventory models on selected researches
Tabela 1. Główne charakterystyki modeli zapasów w wybranych pracach

Author (s) and published year	Structure of the model	Deterioration	Inventory model based on	Discounted allowed	Demand	Partial backlogging allowed	Model is under inflation
Panda et al. (2009)	Crisp	Yes	EOQ	Yes	Stock dependant	Yes	No
Chung et al. (2007)	Crisp	Yes (exponential)	EOQ	No	Selling price	Yes	No
Skouri et al. (2007)	Crisp	Yes weibno	EOQ	No	Ramp	Yes	No
Jaber et al. (20008)	Crisp	Yes on hand inventory	EnOQ	No	Unit selling price	No	No
Uthaya kumar et.al. (2009)	Crisp	Yes (constant)	EOQ	No	Stock dependant	Yes	Yes
Present chapter (2017)	Crisp	Yes (constant)	EnOQ	Yes	Stock dependant	Yes	Yes

Recently Wee et al. (2001) developed a replenishment policy for non-instantaneously deterioration with stock-dependant demand and deprival backlog. In this article an inventory model by introducing entropy cost for analyzing the given replenishment policy has been developed. The profit maximization is developed with crisp stock dependant consumption rate by considering the effect of partial backlogging under inflation with cash discount and time value of money on replenishment with zero lead time also considered.

Numerical examples are presented to demonstrate the developed model and to illustrate the procedure. In addition, the sensitivity analysis of the optimal solution with respect to parameters of the system is carried out.

The rest part of the chapter is arranged as follows: In introduction the literature review is discussed on the effects of exponential deterioration, partial backordering, lost sale and price dependent demand rate and the model is positioned in relative to the previous work. In section 2, the detail model assumptions and notations are explained. In section 3, the model is formulated as a cost minimization problem. In section 4, numerical example is given to illustrate the model. Sensitivity analysis of various parameters is taken in section 5. In section 6 conclusion of this work is summed and directions for future research are suggested.

ASSUMPTIONS AND NOTATIONS

- The replenishment rate is infinite and lead time is zero.
- T_1 is the length of time in which the inventory has no shortages, T is the length of order cycle, Q is the order quantity per cycle. $t_1, T\ and\ Q$ are decision variables.
- The demand rate D(t) at time t is $D(t)=\begin{cases} a+bI(t) & I(t)>0 \\ a & I(t)\le 0 \end{cases}$,where a and b are positive constants, $0 < b \le 1$.
- Shortage are allowed to occur, only a fraction $\delta\ (0 \le \delta \le 1)$ of it is backlogged. The remaining fraction of δ is lost.
- t_d is the length of time in which the product has no deterioration (fresh product time). After this period, a constant fraction $\theta\ (0 < \theta < 1)$ of the on head inventory deteriorates and there is no repair or replenishment of the deteriorated limits $r\ (0 \le r \le 1)$ is the percentage discount offer on unit selling price during deterioration.
- $\alpha = (1-r)^{-n}$ $(n \in R\ the\ set\ of\ real\ numbers)$ is the effect of discounted selling price on demand during deterioration. α is determined from priori knowledge of the seller such that the demand rate is influenced with the reduction rate of selling price. It is obvious that when $r \to 0, \alpha \to 1$ it states demand of decreased quality items remains same.

Notations

- A, h, d, s, π, P and s_1 denote the ordering cost per order, inventory holding cost per unit time, deteriorating cost per unit, the shortage cost for back logging items, the unit cost of lost sales, purchase cost per unit and selling cost per unit respectively. All the cost parameters are positive constant.
- $I_1(t)$ denotes the inventory level at time $t, (0 \le t \le t_d)$ in which the product has no deterioration. $I_2(t)$ is the inventory level at time t, $(t_d \le t \le t_1)$ in which the product has deterioration with price discount $I_3(t)$ denotes the inventory level at time $t, (t_1 \le t \le T)$ in which the product has shortage.
- $T_C(t_1,T)$ is the present value of total relevant inventory cost per unit time of inventory system.
- R represents the net discount rate of inflation and it is constant.

MODEL FORMATION

In this article, the replenishment problem of a single non-instantaneous deteriorating item with partial backlogging is considered. The inventory system goes like this: I_m unit of items arrive at the inventory system at the beginning of each cycle. During the time interval $[0,t_d]$, the inventory level is decreasing only owing to stock dependant two component demand rate. The inventory level is dropping to zero due to demand and deterioration with cash discount on selling price during the time interval $[t_d , t_1]$. Then shortage interval keeps to the end of the current order cycle. The whale process is repeated.

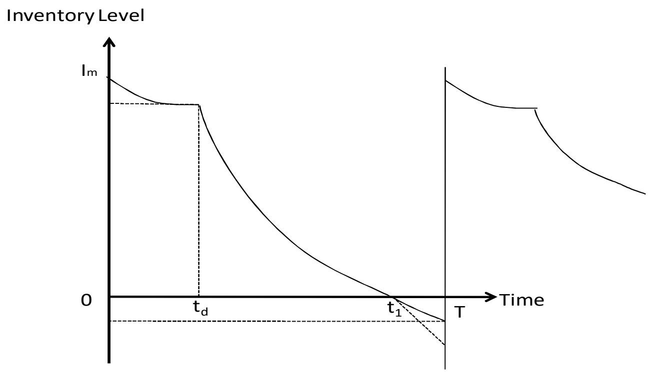

Fig. 1. Graphical representation of inventory system
Rys. 1. Graficzne przedstawienie systemu zapasów

Therefore the inventory system at any time t can be represented by the following differential equations.

$$\frac{dI_1(t)}{dt} = -(a + bI_1(t)),\ 0 \le t \le t_d \ ....(1)$$

$$\frac{dI_2(t)}{dt} = -\alpha(a + bI_2(t)) - \theta\ I_2(t),\ t_d \le t \le t_1 \ ....(2)$$

$$\frac{dI_3(t)}{dt} = -a\delta,\ t_1 \le t \le T \ ....(3)$$

The solution of the above differential equation after applying the boundary conditions $I_1(0) = I_m$, $I_2(t_1) = 0$, $I_3(t_1) = 0$ are

$$I_1(t) = e^{-bt} I_m - \frac{a}{b}\left[1 - e^{-bt}\right],\ 0 \le t \le t_d \ ....(4)$$

$$I_2(t) = \frac{\alpha\, a}{\theta + b\alpha}\left[e^{(\theta + b\alpha)(t_1 - t)} - 1\right],\ t_d \le t \le t_1 \ ....(5)$$

$$I_3(t) = -\delta a\ (t - t_1),\ t_1 \le t \le T \ ....(6)$$

Considering the continuity of I(t) at $t = t_d$ it follows that $I_1(t_d) = I_2(t_d)$ which implies that the maximum inventory level where m is maximum for each cycle is

$$I_m = \frac{\alpha\, a}{\theta + b\alpha}\left[e^{(\theta + b\alpha)(t_1 - t_d)} - 1\right]e^{bt_d} + \frac{a}{b}\left[e^{bt_d} - 1\right] ....(7)$$

Substituting equation (7) into equation (4) it gives

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$$I_1(t) = \frac{\alpha a}{\theta + b\alpha}\left[e^{(\theta+b\alpha)(t_1-t_d)} - 1\right]e^{-b(t-t_d)} + \frac{a}{b}\left[e^{-b(t-t_d)} - 1\right] \text{.......}(8)$$

The maximum amount of demand backlogged per cycle where b is backlog is given by

$$I_b - I_3(T) = \delta a(T - t_1) \text{.................}(9)$$

From equation (7) and (9) the order quantity is obtained.

Q as $Q = I_m + I_b = \frac{\alpha a}{\theta + b\alpha}\left[e^{\theta+b\alpha(t_1-t_d)} - 1\right]e^{bt_d} + \frac{a}{b}\left[e^{bt_d} - 1\right] + \delta a(T - t_1) \text{......}(10)$

Next the total relevant inventory cost per cycle consists of the following elements.

(a) Since replenishment is done at the start of the cycle the present value of the ordering cost per cycle is given by $C_r = A$ .... (11)

(b) The present value of inventory holding cost per cycle is given by

$$C_h = h\int_0^{t_d} I_1(t)e^{-Rt}\,dt + h\int_{t_d}^{t_1} I_2(t)e^{-Rt}\,dt$$

$$\Rightarrow C_h = \frac{ah}{\theta + b\alpha}\left\{\begin{matrix}\frac{\theta + b\alpha}{b\alpha R}\left(e^{-Rt_d} - 1\right) + \frac{1}{b+R}\left(e^{bt_d} - e^{-Rbd}\right)\left(e^{(\theta+b\alpha)(t_1-t_d)} + \frac{\theta}{b} + (\alpha - 1)\right) + \frac{1}{R}\left(e^{-Rt_1} - e^{-Rtd}\right) \\ + \frac{1}{\theta + b\alpha + R}\left(e^{(\theta+b\alpha)(t_1-t_d)} - Rtd - e^{-Rt_1}\right)\end{matrix}\right\}(12)$$

(c) The present value of deterioration cost per cycle is given by

$$C_d = d\int_{t_d}^{t_1}\theta I_2(t)e^{-Rt}\,dt = \frac{d\theta\alpha a}{\theta + b\alpha}\left[\frac{1}{R}\left(e^{-Rt_1} - e^{-Rt_d}\right) + \frac{1}{\theta + b\alpha + R}\left(e^{(\theta+b\alpha)(t_1-t_d)-Rt_d} - e^{-Rt_1}\right)\right] (13)$$

(d) The present value of shortage cost per cycle due to backlog is given by

$$C_s = s\int_{t_1}^{T}\left[-I_3(t)\right]e^{-Rt}\,dt = \frac{sa\delta}{R^2}\left[e^{-Rt_1} - e^{-RT}\left(R(T - t_1) + 1\right)\right] \text{.........}(14)$$

(e) The present value of opportunity cost per cycle due to lost sales is given by

$$C_0 = \pi\int_{t_1}^{T} a(1 - \delta)e^{-Rt}\,dt = \frac{\pi a(1 - \delta)}{R}\left(e^{-Rt_1} - e^{-RT}\right) \text{.......}(15)$$

(f) The present value of the purchase cost per cycle is given by

$$C_p = PI_m + Pe^{-RT} I_b$$
$$= P\left[\frac{\alpha a}{\theta + b\alpha}\left\{e^{(\theta+b\alpha)(t_1-t_d)} - 1\right\}e^{bt_d} + a/b\left(e^{bt_d} - 1\right) + e^{-RT}\delta a\left(T - t_1\right)\right] \text{........}(16)$$

(g) The present value of the entropy cost per cycle is given by

$C_e = e^{-Rt}$[(C_e) without deterioration+(C_e) with deterioration]

$$= \left(\frac{D(t_d)}{\delta(t_d)} + \frac{D(t_1)}{\delta(t_1)}\right)e^{-Rt}$$

$$= \left[\frac{\int_0^{td} d(t_d)dt}{\int_0^{t_d} \frac{d(t_d)dt}{s_1}} + \frac{I_m}{\int_0^{t_d} \frac{d(t_1)dt}{s_1}}\right]e^{-Rt}$$

$$= e^{-Rt}\left[\frac{s_1 \int_0^{t_d}(a + bI_1(t))dt}{\int_0^{td}(a + bI_1(t))dt} + \frac{I_m s_1}{\int_0^{t_1}(a + bI_2(t))} dt\right]$$

$$= e^{-Rt}\left[s_1 + \frac{I_m s_1}{\int_0^{t}[a + bI_2(t)]dt}\right]$$

$$= e^{-Rt}\left[s_1 + \frac{I_m s_1}{a(t_1 - t_d) + \frac{ab\alpha}{(\theta + b\alpha)^2}\left\{\left(e^{(\theta+b\alpha)(t_1-t_d)} - 1\right) - (t_1 - t_d)\right\}}\right].$$

$$\Rightarrow C_e = \left[s_1 e^{Rtd} + \frac{I_m S_1 e^{-Rt_1}}{a(t_1 - t_d) + \frac{ab\alpha}{(\theta + b\alpha)^2}\left\{\left(e^{\theta+b\alpha(t_1-t_d)} - 1\right) - (t_1 - t_d)\right\}}\right] \text{........}(17)$$

Therefore the present value of total inventory cost per unit time is given by = $\frac{TC_1}{T}$

$$TC(r,t_1,T)=\frac{a}{T}\left[\begin{array}{l}\frac{A}{a}+\frac{h}{\theta+b\alpha}\left\{\frac{\theta+b\alpha}{b\alpha R}\left(e^{-Rtd}-1\right)\right\}\\ +\frac{1}{b+R}\left(e^{btd}-e^{-Rtd}\right)\left(e^{(\theta+b\alpha)(t_1-t_d)}\right)+\frac{\theta}{b}+(\alpha-1)+\frac{1}{R}\left(e^{-Rt_1}-e^{-Rtd}\right)\\ +\frac{1}{\theta+b\alpha+R}\left(e^{\theta+b\alpha(t_1-t_d)-Rtd}-e^{-Rt_1}\right)\end{array}\right)$$

$$+\frac{d\theta\alpha}{\theta+b\alpha}\left[\frac{1}{R}\left(e^{-Rt_1}-e^{Rtd}\right)+\frac{1}{\theta+b\alpha+R}\left(e^{(\theta+b\alpha)(t_1-t_d)-Rtd}-e^{-Rt_1}\right)\right]+\frac{s\delta}{R}\left[e^{-Rt_1}-e^{-RT}\left(e^{R(T-t_1)}+1\right)\right]$$

$$+\frac{\pi(1-\delta)}{R}\left(e^{-Rt_1}-e^{-RT}\right)+P\left[\frac{\alpha}{\theta+bd}\left(e^{(\theta+b\alpha)(t_1-t_d)}-1\right)e^{btd}+\frac{1}{b}\left(e^{btd}-1\right)+e^{-RT}\delta(T-t_1)\right]+\frac{1}{a}$$

$$\left[e^{-Rtd}s_1+\frac{I_m s_1 e^{-Rt_1}}{a(t_1-t_d)+\frac{ab\alpha}{(\theta+b\alpha)^{2.}}\left[\left(e^{(\theta+b\alpha)(t_1-t_d)}-1\right)-(t_1-t_d)\right]}\right] \text{..........(18)}$$

Applying this constraint on unit total cost function the following minimization problem has been formulated. Minimize Tc (r, t_1, T) s.t $\forall\ r, t_1\ T \geq 0$.

NUMERICAL EXAMPLE

Given that a is 600, t_d is 0.0833, A is 250, θ is 0.08, β is 0.1, h is 0.5, R is 0.1, δ is 0.56, s is 2.5, π is 2, p is 4, s_1 is 20 and d is 1.5. The Table 2 gives the optimal results of the proposed model and the EOQ model. It is observed that for EnOQ model the total cost per unit time is little more than that of the traditional model but it can be manageable as the hidden cost that is entropy cost is taking into account.

Table 2. Optimal solution
Tabela 2. Optymalne rozwiązanie

Parameter	Iteration	T	t_1	α	I_m	Q	r	EC	TC/Unit time
Optimal Solution (EnOQ)	179	2.580376	0.69772	1	443.2595	1075.832	0	243.2822	2472.518
Optimal Solution (EOQ)	154	1.425254	0.2543475	1	155.2852	548.7098	0	-	2339.773

SENSITIVITY ANALYSIS

Show the relative changes of T, t_1, I_m , Q and TC when each of parameter A, h, d, s, π , p, R, δ , t_d ,Q a and b changes from -15% to 15%.

- The Length of order cycle T and length of time in which inventory has no shortage t_1 are insensitive with respect to parameter A from –10% to 15% but they are sensitive to A at –15% maximum inventory level, Im order quantity, Q and present value total relevant inventory cost/time, T_c are highly sensitive to parameter A from –15% to 15%.
- T and t_1 are insensitive, Im and Tc are highly sensitive and Q moderately sensitive with respect to parameter a from –15% to 15%.

- T_1 in sensitive, T moderately and Im, Q and Tc and highly sensitive with respect to parameter b from –15% to +15%.
- t_1 is insensitive T is moderately sensitive and Im, Tc and Q are highly sensitive with respect to parameter θ from –15%, to +15%.
- t_1 insensitive to parameter R, and moderately sensitive to parameter R but Q & Tc highly sensitive with respect to parameter R from –15% to 15%
- t_1 insensitive , T moderately sensitive and Im, Q & Tc are highly sensitive with respect to parameter δ from –15% to +15%.
- t_1 insensitive, T moderately and Im, Tc & Q are highly sensitive with respect to parameter t_d from –15% to +15%.
- T and t_1 insensitive & Tc, I_m and T_c are highly sensitive and Q is moderately sensitive with respect to parameter h from –15% to 15%.
- t_1 is insensitive , T is moderately sensitive to the parameter d from –15% to 15% but I_m T_c and Q are moderately sensitive with respect to parameter from –10% to +10%., but highly sensitive to parameter at –15% to +15%..
- T and t_1 insensitive with respect to parameter s, but I_m , Q and T_c are highly sensitive with respect to parameter s from –15% to +15%..
- T and t_1 are insensitive with respect to parameter P but I_m Q and T_c are highly sensitive to parameter P from –15% to +15%.
- T, t_1 are insensitive to parameter π . But Q T_c & I_m are highly sensitive to parameter π from –15% to +15%.

Table 3. Sensitivity analysis
Tabela 3. Analiza wrażliwości

$T>t_1$

				1.425254	**0.2543475**	**1**	**155.2852**	**548.7098**	**2339.773**	
Parameter	**%**	**Value**	**Iteration**	**T**	**t_1**	**A**	**I_m**	**Q**	**TC/Unit time**	**% Change**
t_d (0.83)	15%	0.095795	67	0.7655080	0.7655080	1	488.9143	488.9143	3019.785	29.06333221
	10%	0.091630	55	1.428812	0.2569799	1	156.8586	550.5941	2399.507	2.552982704
	5%	0.087465	63	0.7650241	0.7650241	1	488.8725	488.8725	3021.869	29.15222972
	-5%	0.079135	60	1.423498	0.2530397	1	154.5045	547.7786	2339.910	5.855268866
	-10%	0.7197	70	1.121758	0.7650241	1	153.7278	546.8548	2340.049	0.011796016
	-15%	0.070805	64	1.420034	0.2530397	1	152.9552	545.9384	2340.191	0.01786498
H (0.5)	15%	0.575	55	1.1406417	0.2517376	1	147.0351	538.5786	2340.753	0.041884405
	10%	0.55	87	1.412466	0.2504412	1	149.6845	541.8307	2340.436	0.028336082
	5%	0.525	95	1.418740	0.2411092	1	152.4326	545.2054	2340.110	0.014403106
	-5%	0.475	62	1.432021	0.2453639	1	158.2483	552.3515	2339.426	0.014830498
	-10%	0.45	60	1.439056	0.2497737	1	161.3286	556.1389	2339.066	0.032780957
	-15%	0.425	59	0.7858475	0.7858475	1	503.2884	503.2884	3005.109	28.43592092
D (1.5)	15%	1.725	72	0.7601127	0.7601127	1	485.6604	485.6604	3026.222	29.33827341
	10%	1.65	57	1.422929	0.2527923	1	154.3150	547.4810	2339.846	3.119960783
	5%	1.575	61	1.424086	0.2535663	1	154.7978	548.0925	2339.810	1.581349986
	-5%	1.425	57	1.426433	0.2551358	1	155.7771	549.3329	2339.736	1.581349986
	-10%	1.35	65	1.427623	0.2559316	1	156.2737	549.9619	2339.699	3.162699971
	-15%	1.275	69	0.769605	0.7695605	1	492.1225	492.1225	3019.593	29.05495533
S (2.5)	15%	2.875	60	1.302377	0.2799162	1	171.2752	514.8222	2389.846	21.140079401
	10%	2.75	60	1.337350	0.2712147	1	165.8252	524.0467	2374.103	1.467236352
	5%	2.625	67	0.7647924	0.7647924	1	488.8598	788.8598	3022.920	29.19714861
	-5%	2.375	57	1.48186	0.2466482	1	150.4846	565.5161	2320.958	0.804137837
	-10%	2.25	95	1.550854	0.2399893	1	146.3382	586.7888	2300.844	1.663793881
	-15%	2.125	69	1.637730	0.2351378	1	143.3203	614.4568	2279.231	2.587515968
P (4)	15%	4.6	69	1.270375	0.0885177	1	53.34700	450.4509	2539.664	8.543179189
	10%	4.4	58	1.333377	0.1461492	1	88.42954	250.0000	2475.106	5.84022638
	5%	4.2	60	0.7549177	0.7549137	1	482.1117	482.1117	3150.703	34.65849037
	-5%	3.8	78	1.457770	0.3059839	1	187.6532	574.6534	2269.122	3.019566428

Parameter	%	Value	Iteration	1.425254	0.2543475	1	155.2852	548.7098	2339.773	
				T	**t_1**	**A**	**I_m**	**Q**	**TC/Unit time**	**% Change**
	-10%	3.6	63	0.7858060	0.7858060	1	503.2599	503.2599	2766.995	18.25912172
	-15%	3.95	64	1.4932050	0.3813550	1	235.4425	609.0241	2159.429	7.707756265
Π (2)	15%	2.3	60	1.539397	0.3391898	1	208.6276	610.8893	2397.748	2.477676253
	10%	2.2	67	0.7647924	0.7647924	1	488.8598	488.8598	3022.920	29.19714861
	5%	2.1	69	0.7647924	0.7647924	1	488.8598	488.8598	3022.920	29.19714861
	-5%	1.9	63	1.383891	0.2242078	1	136.5309	526.1845	2319.588	0.862690526
	-10%	1.8	57	1.340125	0.1930243	1	117.2338	502.6598	2298.908	1.74653695
	-15%	1.7	55	1.293763	0.167076	1	97.34954	478.056		2.653505276
A (250)	15%	287.5	170	1.586078	0.3117994	1	191.3175	619.4751	2364.687	1.064801874
	10%	275	89	1.533769	0.2932198	1	179.6241	596.4487	2356.673	0.72229229
	5%	262.5	67	1.480208	0.2740886	1	167.6243	572.8803	2348.378	0.367769933
	-5%	237.5	62	1.368744	0.2339277	1	142.5679	523.8663	2330.825	0.382430261
	-10%	225	58	1.310482	0.2127470	1	129.4261	498.2652	2321.494	0.781229632
	-15%	213.5	63	0.7088355	0.7088355	1	450.7786	450.7786	2973.385	0.27080629
A (600)	15%	690.0	57	1.274061	0.1994402	1	139.3746	554.6082	2662.974	13.8121946
	10%	660.0	76	1.321216	0.2166588	1	145.0344	553.2787	2555.543	9.221834768
	5%	630.0	78	0.747049	0.7470499	1	500.5809	500.5809	3157.530	34.95027082
	-5%	570.0	72	1.483060	0.2751102	1	159.8508	545.4284	2231.381	4.632586153
	-10%	540.0	60	1.545497	0.2973944	1	164.0232	541.4495	2122.630	9.280515674
	-15%	510.0	55	1.613305	0.3214295	1	167.7847	536.7444	2013.500	13.94464335
B (0.1)	15%	0.115	56	1.409248	0.2431289	1	148.5650	540.3809	2340.587	0.034789699
	10%	0.110	62	1.414415	0.2467537	1	150.7375	543.0717	2340.323	0.024556059
	5%	0.105	56	1.419748	0.2504914	1	152.9765	545.8466	2340.052	0.011924233
	-5%	0.095	56	6.7714445	0.7714445	1	492.4404	492.4404	3017.723	28.97503305
	-10%	0.090	56	1.436823	0.2624387	1	160.1256	554.7188	2339.194	0.02474599
	-15%	0.085	64	1.442906	0.266869	1	162.6648	557.8744	2338.892	0.037653225
θ (0.08)	15%	0.092	63	0.7453963	0.7453963	1	477.3446	477.3446	3036.032	29.75754486
	10%	0.088	67	0.7516999	0.7516999	1	481.0894	481.0894	3031.704	29.57256965
	5%	0.084	83	1.420820	0.2513832	1	153.4710	546.4018	2339.911	5.898008055
	-5%	0.076	62	1.429852	0.2574197	1	157.1651	551.1024	2339.631	6.08696481
	-10%	0.072	90	1.434623	0.2606058	1	159.1145	553.5843	2339.484	0.012351625
	-15%	0.068	62	0.785754	0.785754	1	501.2790	501.2790	3009.410	28.61974217
R (0.1)	15%	0.115	61	1.630185	0.3015068	1	184.8348	631.2705	2307.025	1.399622955
	10%	0.110	70	0.7656045	0.7656045	1	489.4153	489.4153	3022.561	29.18180524
	5%	0.105	61	1.483599	0.2675229	1	163.5155	572.1170	2329.251	0.449701744
	-5%	0.095	60	1.373965	0.2429770	1	148.1980	528.2100	2349.965	0.435597812
	-10%	0.090	71	1.328349	0.2330591	1	142.0280	510.0455	2359.868	0.858843999
	-15%	0.085	70	0.7635736	0.7635736	1	488.0263	488.0263	3023.459	29.22018504
Δ (0.56)	15%	0.44	34	1.429330	0.0833	1	508.18871	405.5406	2144.696	8.337432734
	10%	0.616	53	1.432069	0.3366845	1	207.0407	611.8998	2417.212	3.30968004
	5%	0.588	61	1.430699	0.29711	1	182.0692	581.9994	2379.461	1.696232925
	-5%	0.532	63	0.7647924	0.7847924	1	488.8598	488.8598	3022.920	29.19714861
	-10%	0.504	65	0.7647924	7647924	1	488.8598	488.8598	3022.920	29.19714861
	-15%	0.476	59	1.369980	0.1020028	1	61.52333			5.651061022

	Value	**129 Iteration**	**20.21354 P**	**1.235266 T**	**0.6191482** λ	**0.5394279** β	**0.4261269** ψ	**732.4492 Q**
R 1000	2500	353	22.17379	1.059340	0.5744873	0.1584914	0.5165645	71.06637
	3500	97	22.45881	1.040059	0.5692097	0.1088282	0.5294063	148.6316
	7000	393	22.79378	1.019029	0.5633775	0.0520301	0.5443413	216.4142
V 10	30	62	75.10939	1.900610	1.140144	0.07188098	1.118931	83.69563
	31	63	77.99979	1.933427	1.167231	0.06820748	1.147245	88.19348
	32	63	80.90742	1.965797	1.194354	0.06483163	1.175490	93.09398
K 1000	2000	69	19.94523	1.671229	1.014177	0.7751931	0.7136296	1255.4901
	2500	71	19.78269	1.843857	1.189006	0.8797249	0.8426004	1075.7405
	2600	70	19.74758	1.876126	1.223066	0.9001808	0.8677567	1226.1305
H 1.0	1.005	303	20.21297	1.234239	0.6195769	0.5389607	0.4264271	731.7726
	1.01	167	20.21240	1.233214	0.6200051	0.5384944	0.4267269	729.0999
	1.05	203	20.20781	1.125082	0.6234143	0.5347985	0.4291129	732.1105
σ **0.3**	0.1	174	20.61528	1.931695	0.3843251	0.7716785	0.2637703	713.1654
	0.15	138	20.53548	1.683328	0.4553440	0.6896130	0.3134129	892.2333
	0.35	124	22.09903	1.137771	0.6623002	0.5059868	0.4551216	831.5441
K_0 **0.9**	0.900	269	20.21073	1.234580	0.6201478	0.5392356	0.4266828	732.952
	5	103	20.20791	1.233893	0.6211467	0.5390429	0.4272376	733.4544
	0.901	317	20.20228	1.232517	0.6231424	0.5386562	0.4283442	732.7006
	0.902							
K_1 **0.6**	1.5	198	20.71899	1.339248	0.2720504	0.5638406	0.1925615	643.3295
	2	80	20.84976	1.360799	0.2074038	0.5673938	0.1477464	624.6882
	2.1	63	20.87001	1.364000	0.1979906	0.5678748	0.1411772	627.0512

	303.013642 I	**55.70604008** θ	**27.87.508** $\pi - T.P$	**D =160000×**P^{-2} **= 391.5932762**
R 1000	318.5260656	−261.7849189	2615.212	3307.955013
	340.7842482	−221.0886556	2588.924	317.2097502
	365.0751441	−186.2357538	2557.973	325.4169141
V 10	59.54654071	64.83163	588.4313	24.44236796
	65.738938	17.36099978	558.9211	26.29862944
	72.67949529	17.97654196	531.4737	28.36165128
K 1000	421.7896649	130.4227826	2346.091	410.2912157
	449.6750913	103.0250766	2171.146	402.1998322
	463.5557312	125.8895	2138.530	408.8361516
H 1.0	302.777236	55.52161378	2787.007	391.63745
	302.645141	540.7920677	2786.508	391.8153832
	252.8955616	55.61374704	2782.534	391.6153622
σ **0.3**	454.563222	133.2275581	3070.321	327.6223791
	435.85808	44.43464095	2980.847	376.4796508
	263.9282936	50.93932913	2739.673	379.4113036
K_0 **0.9**	302.943705	55.58942629	2788.134	391.8115053
	302.8738668	55.47266291	2788.762	392.0299169
	302.1434049	55.64792978	2790.020	391.7021742
K_1 **0.6**	325.3904508	64.67594335	2693.627	372.7201061
	329.0638278	54.53960238	2674.549	367.3454528
	330.9740121	66.5389960	2671.725	368.0593563

CONCLUSIONS

In this replenishment finite planning horizon model for deteriorating items with stock dependent consumption rate, shortages are allowed and partial backlogging. By introducing the hidden cost which is related to the total amount of disorder in a production system that is entropy cost to obtain minimum total inventory cost per unit time where r, T and t_1 are decision parameters. Comparative analysis for EOQ and EnOQ models also carried out for framing better managerial decision. When demand is sensitive to the selling price, pricing and production planning problem are intervened, moreover, when a products are perishable, the vender may need to backlog demand in order to avoid high cost due to deterioration. An integrated model for a perishable product has been presented. The backlogging phenomenon is modelled without using the backorder cost and the lost sale cost.

From sensitivity and demand rate are that the total profit and demand rate are highly sensitive to the parameter unit cost, but moderately sensitive to other parameters such as R, K, σ, k_1 and insensitive to the parameter h and K_0. This model may be extended by introducing total backlogging, time value of money, uncertainity, stock and price dependent demand.

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METODA UZUPEŁNIEŃ DLA MODELU ENTROPICZNEJ WIELKOŚCI ZAMÓWIENIA (ENOQ) Z DWUELEMENTOWYM POPYTEM I UWZGLĘDNIAJĄCY INFLACJĘ

STRESZCZENIE. Wstęp: Metoda uzupełnień dla modelu entropicznej wielkości zamówienia (ENOQ) z dwuelementowym popytem i uwzględniający inflację jest istotnym zagadnieniem w obrębie zarządzania zapasem.
Metody: W pracy stworzono model zarządzania zapasem dla pozycji o nierównomiernym zużyciu oraz uwzględniający czynnik inflacyjny w ujęciu wartościowym dla zamówień z zerowym czasem realizacji. Sformułowano model maksymalizacji zysku przy uwzględnieniu inflacji oraz systemu rabatów gotówkowych. Zaprezentowano przykład numeryczny dla porównania efektów uzyskiwanych przy zastosowaniu modelu entropicznej wielkości zamówienia oraz ekonomicznej wielkości zamówienia. Na przykładzie został zaprezentowany stworzony model oraz została zilustrowana procedura. Oprogramowanie Lingo 13.0 zostało wykorzystane do wyprowadzenia optymalnej wielkości zamówienia oraz całkowitego kosztu zapasu. Następnie przeprowadzono analizę wrażliwości optymalnego rozwiązania dla różnych parametrów.
Wyniki i wnioski: Otrzymany model zapasu jest bardzo przydatny w przedsiębiorstwie handlu detalicznego. Może on został użyty również w szerszym zakresie.

Słowa kluczowe: entropiczna wielkość zamówienia, popyt dwuskładnikowy, częściowe zużycie, inflacja

EINE ERGÄNZUNGSMETHODE FÜR DAS MODELL DER ENTROPISCHEN BESTELLUNGSGRÖßE (ENOQ) BEI EINER DIE INFLATION BERÜCKSICHTIGENDEN ZWEI-ELEMENTEN-NACHFRAGE

ZUSAMMENFASSUNG. Einleitung: Die Ergänzungsmethode für das Modell der entropischen Bestellungsgröße (ENOQ) bei einer die Inflation berücksichtigenden Zwei-Elementen-Nachfrage stellt eine wesentliche Fragestellung im Bereich der Bestandsführung dar.
Methoden: Im Rahmen der Arbeit wurde ein Bestandsführungsmodell für die Position von ungleichmäßigem Verbrauch, das den Inflationsfaktor bei wertmäßiger Betrachtung für Bestellungen mit dem Null-Wert der Ausführungszeit mit berücksichtigt, ausgearbeitet. Man konzipierte dabei ein die Inflation und das System von Barrabatten berücksichtigendes Modell für die Gewinnmaximierung. Zwecks des Vergleiches der unter Verwendung des Modells der entropischen und der wirtschaftlichen Bestellungsgröße erzielten Ergebnisse wurde ein nummerisches Beispiel dargestellt. Anhand des Beispiels wurde das konzipierte Modell präsentiert und die betreffende Prozedur projiziert. Zwecks der Ableitung der optimalen Bestellungsgröße und der Gesamt-Bestandskosten wurde die Software Lingo 13.0 in Anspruch genommen. Demzufolge wurde eine Analyse der Empfindlichkeit von optimalen Lösungen für unterschiedliche Parameter durchgeführt.

Ergebnisse und Fazit: Das betreffende Bestandsführungsmodell ist im Einzelhandel-Unternehmen sehr brauchbar. Es kann auch im breiteren Ausmaße benutzt werden.

Codewörter: entropische Bestellungsgröße, Zwei-Elementen-Nachfrage, teilweiser Verbrauch, Inflation

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