An Economic Production Quantity Model for Atlantic Pharmaceuticals Laboratories

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***Abstract*--Inventory in an industry is considered like a blood in the body, and almost 50% of investment is made on inventory. Therefore, keeping the optimum level of inventory at low possible cost is the primary focus of researchers. Industries have to make good choices for inventory management in order to compete in market and meet the demands. Major issues regarding inventory in pharmaceutical industry are overstock, unjustified forecasting technique, long manufacturing lead times and lack of IT support. For these reasons, optimizing inventory is more difficult for pharmaceutical companies as compared to other manufacturing companies. Such issues are also faced by Atlantic Pharmaceuticals Laboratories (APL). In order to address these issue, inventory management is performed in APL. Inventory is categorized in three classes through ABC analysis. Class A items are further analyzed and their optimum quantity is determined by EPQ model. At the end sensitivity analyses are performed to determine the most and least critical parameters of the model.**

Keywords: Inventory management, ABC Analysis, EPQ model, Sensitivity analysis

I. INTRODUCTION

Determining the right level of inventory in any organization has been the primary focus nowadays. In order to survive and groom up in modern competition, the organization has to make good decision about its inventory. Here the focus is on an inventory management in Atlantic Pharmaceutical laboratories (APL). Inventory may consist of foods, finished products and raw materials that contain financial value and are stored by any company or firm in different forms in its supervision waiting for various operations such as stuffing or sale of products in the future point of view. Inventory management system tracks products with entire supply chain or the portion of it. Thus, inventory management system covers everything from the production to retailers, warehousing to packing so that all the movements of stock & parts between the manufacturer and retailer is done in optimum way. We mean that one of the business company can see all the movements of the small parts of its processes, which can help to make healthy decisions and investments, different managers focus on different parts of the supply chain. That’s why small business focuses or concentrates at the end of the sales of the chain.

Whenever there is a good tracking stuff then there are a lot of chances to make investment and take advantages of that. When we track our product then we estimate that how to much we can sell in the future, we can find out it for the customer and reorder whenever there is stock out appearance. For this purpose, that when to do tracking, predicting and reordering is to use an inventory management system. We will look at what that means, what are the parameters to be lookout for, and what how we can accomplish a good inventory system in place. Inventory is a very important stuff that the company need to keep for different activities. To keep the inventory optimum this is the desired objective of each and every company. Overstock and shortage of inventory both damage economical influence and health of the commercial as well as disturb business events. Technology is used in probably each and every field of inventory management to help control, monitor, and analyze inventory level. Computers, especially, play a massive role in current inventory management.

Inventory is the expensive assists of any organizations which covers 50 % of the total capital investment just on inventory. Operation controller of the entire world have considered that inventory management is very important because a company can reduced inventory cost by reducing their inventory also the stock out can result in customers dissatisfaction. All of the organization have their own inventory about which they are carrying to control it through some methods and planning i.e. a bank has its inventory management system for cash to control it. Like other organization, Hospitals control the inventory of types of blood, pharmaceutical’s, Library controls inventory of books, Government agencies, schools, colleges, restaurant’s and that’s why almost every production firm is looking to control their inventory through some methods and planning.

A. Problem Description

APL deals with products like syrup, suspension and infusion, the raw material which is ordered for such kind of product is through experienced guess not through technical method, which often cause the shortage of inventory or excess of inventory, and causing additional cost. Thus, developing a technique for this kind of problem and making sure that, the desired demand is fulfilled exactly when the customer needs it with minimum inventory cost associated.

B. Objectives

The main objective of the inventory management is to make an equilibrium between inventory investment and customer service. Applying the best methodology based on the inventory problem to achieve the following objectives:

- Optimum inventory level
- Minimum inventory cost

II. LITERATURE REVIEW

Everyone knows that inventory management plays the major role in every type of business organization to flourish it. Production Order Quantity (POQ) model is one of the most common inventory model which is used in inventory control techniques. This almost the first inventory model developed by Harris in 1913. This model calculates the quantity in order to minimize inventory cost, by determining the optimum level for the related costs. This model tells us about the level of optimum amount of items production and therefore it is mostly applicable to manufacturing organization. S.M. Samak- Kulkarni contributed in the determination of finest inventory model for decreasing inventory cost [1]. Inventory is the stuff of raw material, WIP and finished goods used in organization. To solve order related problems, they present some models on which they work to solve inventory related problem which will reduce the total inventory cost and will optimize the inventory level. These papers take into consideration lot by lot size, economic order quantity (EOQ), periodic order quantity (POQ) and Wagner Within algorithm. In this paper total inventory cost for many items are determined for each method so in the results after calculation for each model the Wagner Within algorithm gives the optimum cost in each case.

Lt Col Gupta researched to control the inventory of medical store by using ABC-VED analysis in a combination to divide the whole inventory in three categories I, II, and III [2]. The methods which were used by the authors in this case study are ABC-VED analysis, and the economic analysis of the Pharmaceutical Spending of Priced Vocabulary Stores (PVMS) section 01 hospital for the year 2003 was under consideration which was consists of 190 bedded service. The total drugs were 493 drugs in PVMS Section 01, and in these drugs only 325 were being used in the reference hospital which costs about 55,23,503 rupees. So this 325 drugs were categorize in such a way that 47 drugs (about 14.4%) were added to category A which consume 70% of the total expenditure because these drugs were high in the cost but were low in the amount (about 14.4%) as mentioned earlier, Hooshang researched on inventory management by using ABC Classification and decision support system with a clinical laboratory application [3]. For this clinical laboratory the ABC classification is based on the criteria of annual dollar volume which categorize the items intro three classes. The Pareto principle is usually applicable to ABC classification which suppose that 20% of the items will generate 80% of the annual dollar volume of the demand. So, this idea motivate inventory controller to concentrate on few of the items of the inventory which are the most critical items regarding annual dollar value.

The class A items are the highest annual dollar demand items (about 78-80 %) of the budget which are forcefully managed which requires a high attention from both class B and C items. The 15-20 % of the total items of the laboratory include in class A which is less but very critical due to its annual dollar value while 15-25% annual dollar volume generates by class B which included 25-30% of the items and class C with low annual dollar volume values but includes large portion of the inventory. The Class B and Class C items are placed at a higher level than Class A items. The company uses ABC classification for the 47 items in which the first 8 items were classified in Class A which accounted for 77% of the annual demand cost. 4 items were classified in Class B and the remaining 17 items were classified in Class C using Lean Production, Organizational Performance and Inventory Management [4]. The purpose of this case study was to check the hypothesis that with the implementation of lean inventory management will leads to improve the financial performance of a firm. Now in this case study they analyze the data which came from the ICAP database, which includes financial information. The data were taken in between 2000 and 2002 period which was the sample period for the data analysis. The industrials sectors which were selected in Greece were Food, Textiles and Chemicals. Initial results, from this analysis obtained that the higher the level of inventories conserved by a firm, the lower will be its rate of return.

This kind of inventory models has attracted the attention of several researchers such as Sarkar, Chaudhuri, & Sana [5], Sarkar, Sana, & Chaudhuri [5,6,7], Sarker, Jamal, & Mondal [8], Sana & Chaudhuri[6] , Chug [9], Sarkar [10,11,12], Widyadana and Wee [13], Chang, Su, Yang, & Weng, [14]) and Cárdenas-Barrón, Sarkar, & Treviño-Garza [15], Cárdenas-Barrón, Taleizadeh, & Treviño-Garza [16] , just to name a few works. MS Mahatme, et al

[17] researched an integrated Economic model analysis of a Teriary Care Hospital in Central India. Financial study plays an essential role in the management of medical store. Hospital inventory management system should ensure the optimum stock of all the required items to keep the supply without any interruption. About one third of the hospital revenue is spent on the materials and pharmaceuticals. So, this gives importance to manage and control the important drugs in the medical store. The main purpose of this case study was to control the inventory of the medical store by controlling VED analysis with EOQ after the comparison of indexed cost and the actual cost.

III. METHODOLOGY

As mentioned before the industry, which is selected for the proposed work is Atlantic Pharmaceuticals Laboratories (APL). The production process of any pharmaceuticals industry for syrup and suspension production is given in figure 1. APL deal with different products like syrups, suspension and infusion and they follows the same process.

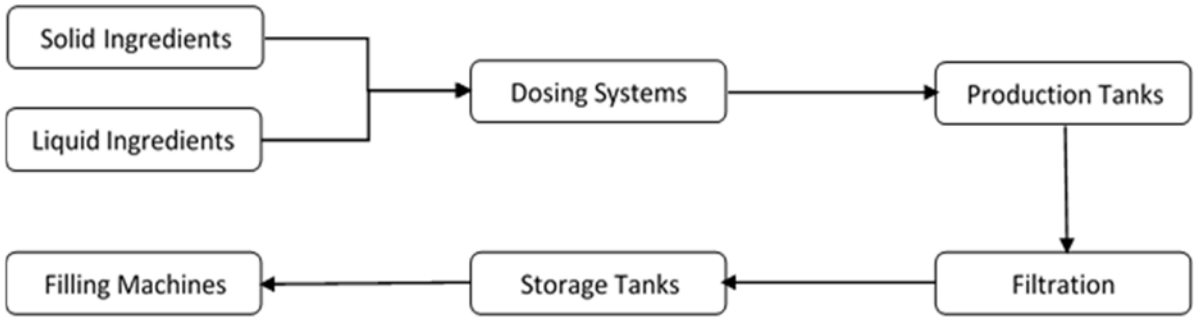

Fig. 1 Production process of Atlantic Pharmaceuticals Laboratories.

First of all, solid ingredients are dissolved into liquid (mostly purified water) and then through dosing systems are fed into the production tanks according to the formulation. The dosing system is powered by an electric motor and has a controller that turns the pump on and off and managed the flow rate. In production tanks the solution is taken to the required temperate and necessary production processes are performed. After the production, the solid particles are separated from the solution through the process of filtration. All the products dispense extemporaneously are stored in the storage tanks and then filled in the bottles when required.

A. Data Collection

APL produces three kinds of products i.e. Syrups, Suspension and Infusions. Table I given below tells about the type of product its registration number their package size and cost associated per unit. For example, look at the product no 1, it shows that it is syrup by name of Acitral having registration no 62316 with a generic name of Sodium acid citrate. The packing of Acitral is 120 ml per pack or bottle with a unit cost of Rs.19.

Table I. Detail of the products in Atlantic Pharmaceuticals Laboratories.

S.NO	Syrup/Suspention /Infusion	Reg. NO	Generic Name	Pack ml	Unit Cost (PKR)
1	Syp. Acitral	62316	Sod.acide citrate	120	19
2	Susp.Alusim	62321	Al.Hydroxide+Mg.Hydroxide	120	19
3	Susp.Alusim	62321	Al.Hydroxide+Mg.Hydroxide	240	35
4	Susp.Calco-D	68497	Calcium Phosphate+Vit-D	120	19
5	Susp.Calco-D	68497	Calcium Phosphate+Vit-D	240	35
6	Syp. Cetrazit	68499	Cetrizine Dihydrocloride	60	15
7	Susp.Dilox-M	62323	Diloxanide Furoate+Met.Benzoate	60	24
8	Susp.Epodom	62318	Domperidone	120	23
9	Susp.Fempol	62314	Paracetamol 120mg	60	15
10	Susp.Fempol 6+	62315	Paracetamol 250mg	60	17
11	Susp.Fempol C	73363	Paracetamol + Chlophenramine	60	16.5
12	Syp. Hydilar	62325	Aminophylline,Diphenhydramine	120	18
13	Syp.Hydilar DM	62317	Diphenhydramine,Dextromethorphen	120	23
14	Syp.Metopride	62322	Metochlopramide HCL	50	16
15	Susp.Metrosol	73362	Metronidazole as Benzoate	60	19
16	Susp.Pepticral	73365	Sucralfate	60	46
17	Susp.Pironec	62324	Ibuprofen	90	20
18	Syp.Rediron	73364	Iron Polymaltose	120	25
19	Syp.Rediron	73364	Iron Polymaltose	240	47
20	Syp.Pizo	68500	Pizotifen	60	20
21	Syp.Pizo	68500	Pizotifen	120	25
22	Syp.Ventasol	73366	Sulbotamol	60	14.5
23	Syp.Zinsol	96701	Zinc Sulphate	60	17
24	Susp.Zoprim	62319	Trimethoprim,Sulfamethoxazole 200 mg	50	18
25	Susp.Zoprim DS	62320	Trimethoprim,Sulfamethoxazole 400 mg	50	23
26	Metrosol Inf	11768	Metronidazole 500mg	100	24
27	Ciprosol Inf	47720	Ciprofloxacine 200mg as Lactate	100	29
28	Lefosol Inf	46104	Levofloxacine 500mg	100	31
29	Oflocin-sol Inf	46105	Ofloxacine 200mg	100	28
30	Transol 5%	52478	Dextrose 5 %	100	19
31	Transol DS	52479	Dextrose 5 % + Nacl 0.9%	100	20
32	Transol N/S	52480	Sodium Chloride 0.9%	100	18

In data collection the first thing is to know how many different kinds of products in the industry producing. APL is producing 32 types of products which include syrups (syp), Suspensions (Susp) and infusions (Inf). The monthly demand of each item from January to December is shown in the table below. The Demand given here is in cottons. Look at the item no 1 with registration no 62316, it shows that the demand of this particular item in January is 300 cottons, in February 308 cottons and so on as shown in Table II.

Table II. Monthly demand for each item.

S.NO	Reg. NO	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. Monthly Demand (Cotton)	Bottles per Cotton	Avg.Total Monthly Demand (Bottles)
1	62316	300	308	298	312	290	295	300	310	290	290	310	305	301	70	21070
2	62321	300	290	304	295	304	308	308	304	298	307	302	292	301	70	21070
3	62321	100	98	108	106	95	95	106	105	90	90	100	105	100	50	5000
4	68497	200	200	190	195	215	205	195	190	190	210	205	205	200	70	14000
5	68497	80	65	90	85	88	70	78	78	80	86	78	82	80	50	4000
6	68499	500	480	485	510	495	505	498	498	506	518	512	492	500	100	50000
7	62323	200	198	210	208	190	190	215	215	186	190	190	205	200	100	20000
8	62318	100	100	108	90	95	105	95	104	108	112	104	90	101	70	7070
9	62314	1000	1030	990	990	1014	1020	980	995	1018	1025	995	1000	1005	100	100500
10	62315	800	810	812	791	792	807	812	800	796	794	796	810	802	100	80200
11	73363	500	488	495	508	505	505	495	496	520	516	494	502	502	100	50200
12	62325	125	120	130	128	112	120	133	132	125	128	127	130	126	70	8820
13	62317	75	77	72	79	65	70	78	75	72	78	78	76	75	70	5250
14	62322	100	94	103	110	98	92	115	90	95	98	108	108	101	120	12120
15	73362	500	500	490	502	505	515	498	490	508	517	502	496	502	100	50200
16	73365	50	48	55	55	45	49	52	56	49	54	54	57	52	100	5200
17	62324	1000	1014	1005	994	986	995	1015	1008	996	990	1018	1003	1002	80	80160
18	73364	300	300	306	295	315	315	310	294	286	290	308	305	302	70	21140
19	73364	100	108	106	97	98	108	110	107	100	92	95	102	102	50	5100
20	68500	200	208	205	194	190	186	204	208	202	212	209	205	202	100	20200
21	68500	400	394	410	414	398	394	392	402	417	397	404	396	402	70	28140
22	73366	100	108	115	94	102	92	97	95	114	98	95	113	102	100	10200
23	96701	200	196	195	207	198	205	200	214	187	208	205	196	201	100	20100
24	62319	100	95	110	98	95	90	112	108	104	95	95	106	101	120	12120
25	62320	100	100	102	115	98	92	94	97	112	110	96	106	102	120	12240
26	11768	250	244	248	245	252	260	254	240	256	262	253	260	252	70	17640
27	47720	500	518	510	493	489	497	510	494	515	520	506	508	505	70	35350
28	46104	50	55	54	49	48	53	50	44	49	47	57	55	51	70	3570
29	46105	50	58	47	51	48	46	53	58	55	60	58	52	53	70	3710
30	52478	1000	986	990	1012	996	1020	1022	1005	995	998	1018	1005	1004	70	70280
31	52479	100	104	98	92	116	105	97	88	104	111	98	108	102	70	7140
32	52480	800	794	798	812	815	808	793	785	810	810	818	815	805	70	56350

At the end of the year the average monthly demand is 301 cottons and as 1 cotton contains 70 units, therefore is 21070 units demand in average for this particular item.

B. Data Analysis

Data is analyzed so that it becomes easier to understand the data and become more help full in problem solving. Here ABC analysis technique is followed, which divides the on-hand inventory into three classes A, B and C on the basis of annual dollar volume as shown in Table III. The detail of each class is discussed in an earlier chapter.

Table. III Item categorization through ABC analysis.

Rank	**Reg. NO**	**Unit Cost (PKR)**	**Avg. Total Monthly Demand (Bottles)**	**Monthly Cost (PKR)**	**Percent of Monthly Cost**	**Cumulative Percent**	**Category**
1	62324	20	80160	1603200	9.56	9.56	A
2	62314	15	100500	1507500	8.99	18.56	A
3	62315	17	80200	1363400	8.13	26.69	A
4	52478	19	70280	1335320	7.97	34.66	A
5	47720	29	35350	1025150	6.12	40.77	A
6	52480	18	56350	1014300	6.05	46.82	A
7	73362	19	50200	953800	5.69	52.51	B
8	73363	16.5	50200	828300	4.94	57.45	B
9	68499	15	50000	750000	4.47	61.93	B
10	68500	25	28140	703500	4.20	66.12	B
11	73364	25	21140	528500	3.15	69.28	B
12	62323	24	20000	480000	2.86	72.14	B
13	11768	24	17640	423360	2.53	74.66	B
14	68500	20	20200	404000	2.41	77.07	B
15	62316	19	21070	400330	2.39	79.46	B
16	62321	19	21070	400330	2.39	81.85	C
17	96701	17	20100	341700	2.04	83.89	C
18	62320	23	12240	281520	1.68	85.57	C
19	68497	19	14000	266000	1.59	87.15	C
20	73364	47	5100	239700	1.43	88.58	C
21	73365	46	5200	239200	1.43	90.01	C
22	62319	18	12120	218160	1.30	91.31	C
23	62322	16	12120	193920	1.16	92.47	C
24	62321	35	5000	175000	1.04	93.51	C
25	62318	23	7070	162610	0.97	94.48	C
26	62325	18	8820	158760	0.95	95.43	C
27	73366	14.5	10200	147900	0.88	96.31	C
28	52479	20	7140	142800	0.85	97.16	C
29	68497	35	4000	140000	0.84	98.00	C
30	62317	23	5250	120750	0.72	98.72	C
31	46104	31	3570	110670	0.66	99.38	C
32	46105	28	3710	103880	0.62	100.00	C

The table above shows us the ABC classification. The rank shows that which one item contributes more to the monthly cost. Take for example rank 1 item with the unit cost of 20 PKR have a demand of 80160 units with monthly cost of 1603200 PKR contributing the highest cost to the monthly inventory cost with 9.56 percent. Similarly, you can see for the other item. The number of items in class A are six contributing to all most 50% of total inventory cost. Similarly, Class B items are nine and class C are 17 contributing 30% and 20% to the total inventory cost respectively. The first two classes A and B are further taken for the management as they are involved in the 80% cost of inventory.

POQ model is used when inventory sizes up over a period of time after an order is placed. It is also used when units are produced and are sold at the same time. The equation for Optimum production quantity is given below:

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

Where,
Q^*_p = Optimum number of units per order
H = Holding cost per unit per year
p = Daily production rate
d = Daily demand rate, or usage rate
t = Length of the production run in days
H = (unit cost) (interest rate i)
Working days per year = 250
Interest Rate i = 10%
Total Cost TC $= \frac{D}{Q}S + \frac{Q}{2}H$
The calculated Q^*_p and TC for the 15 items which includes six items of class A and nine of class B are given in the table below.

Table IV. Optimum production and total cost for class A and B items.

Rank	Reg. NO	Daily Demand	Daily Production	Holding Cost (PKR)	Setup Cost (PKR)	Q^*_p (Units)	TC (PKR)
1	62324	3847.68	3855	2	40	142349.6	80640
2	62314	4824	4834	1.5	24	136584.7	75663
3	62315	3849.6	3860	1.7	30	112280.9	68530
4	52478	3373.44	3400	1.9	35	63067.3	67186
5	47720	1696.8	1730	2.9	48	27050.5	51833.5
6	52480	2704.8	2738	1.8	27	40902.1	51039
7	73362	2409.6	2428	1.9	26	46642.6	48002
8	73363	2409.6	2435	1.65	37	50891.9	41859
9	68499	2400	2391	1.5	54	107129.8	38148
10	68500	1350.72	1342	2.5	60	49944.9	35895
11	73364	1014.72	1050	2.5	48	17027.0	27001
12	62323	960	948	2.4	63	31550.0	24756
13	11768	846.72	894	2.4	41	11694.2	21660
14	68500	969.6	1032	2	45	13431.4	20740
15	62316	1011.36	1083	1.9	34	11696.0	20424.5

Now the total cost here is calculated on the basis of optimum production quantity Q^*_{p}. After that the sensitivity analysis comes which helps in finding the most critical variable or variables which can affect the TC with large scale when they are manipulated.

IV. NUMERICAL COMPUTATION AND SENSITIVITY ANALYSIS

This includes the sensitivity analyses for all the items of class A which were selected as a critical product and are more responsible for inventory cost. The analysis performed for each is given below in detail.

A. Computation for Item No. 1

The data for Susp. Pironec the key variables are taken with appropriate units as follows: D = 961920 units/year, Q = 80160units/order, H = 2 Rs/unit, S = 40/lot size, daily demand d = 3847.68 units, and daily production rate p = 3855 units

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

$$Q_P^* = \sqrt{\frac{2*961920*40}{2[1\left(-\frac{3847.68}{3855}\right)]}}$$

Q_P^*= 142349.6 Units

$$\text{Total Cost } TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$TC = \frac{961920}{80160}40 + \frac{80160}{2}2$$

$$TC = Rs. 80640$$

Table V. Sensitivity analysis for the key parameters of item no. 1

Parameter	Changes	Changes (in %)	Total Cost	Total Cost (in %)
D	1442880	+50	80880	0.2976
	1202400	+25	80760	0.1488
	721440	-25	80520	-0.1488
	480960	-50	80400	-0.2976
Q	120240	+50	120560	49.5040
	100200	+25	100584	24.7321
	60120	-25	60760	-24.6528
	40080	-50	41040	-49.1071
H	3	+50	120720	49.7024
	2.5	+25	100680	24.8512
	1.5	-25	60600	-24.8512
	1	-50	40560	-49.7024
S	60	+50	80880	0.2976
	50	+25	80760	0.1488
	30	-25	80520	-0.1488
	20	-50	80400	-0.2976

B. Computation for Item No. 2

The data for Susp.Fempol the key variables are taken with appropriate units as follows: D = 1206000 units/year, Q = 100500 units/order, H = 1.5 Rs/unit, S = 24 Rs/lot size, daily demand d = 4824 units, and daily production rate p = 4834 units

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

$$Q_P^* = \sqrt{\frac{2 * 1206000 * 24}{1.5[1\left(-\frac{4824}{4834}\right)]}}$$

$$Q_P^* = 136584.7 \text{ Units}$$

$$\text{Total Cost } TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$TC = \frac{1206000}{100500}24 + \frac{100500}{2}1.5$$

$$TC = Rs. 75663$$

Table VI. Sensitivity analysis for the key parameters of item no. 2

Parameter	Changes	Changes (in %)	Total Cost	Total Cost (in %)
D	1809000	+50	75807	0.1903
	1507500	+25	75735	0.0952
	904500	-25	75591	-0.0952
	603000	-50	75519	-0.1903
Q	150750	+50	113254.5	49.6828
	125625	+25	94449.15	24.8287
	75375	-25	56915.25	-24.7780
	50250	-50	38263.5	-49.4290
H	2.25	+50	113350.5	49.8097
	1.875	+25	94506.75	24.9048
	1.125	-25	56819.25	-24.9048
	0.75	-50	37975.5	-49.8097
S	36	+50	75807	0.1903
	30	+25	75735	0.0952
	18	-25	75591	-0.0952
	12	-50	75519	-0.1903

C. Computation for Item No. 3

The data for Susp.Fempol 6+ the key variables are taken with appropriate units as follows: D = 962400units/year, Q =80200 units/order, H = 1.7 Rs/unit, S = 30 Rs/ lot size, daily demand d = 3849.6 units, and daily production rate p = 3860 units

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

$$Q_P^* = \sqrt{\frac{2 * 962400 * 30}{1.7[1\left(-\frac{3849.6}{3860}\right)]}}$$

$$Q_P^* = 112280.9 \text{ Units}$$

$$\text{Total Cost } TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$TC = \frac{962400}{80200}24 + \frac{80200}{2}1.7$$

$$TC = Rs. 68530$$

Table VII. Sensitivity analysis for the key parameters of item no. 3

Parameter	Changes	Changes (in %)	Total Cost	Total Cost (in %)
D	1443600	+50	68710	0.2627
	1203000	+25	68620	0.1313
	721800	-25	68440	-0.1313
	481200	-50	68350	-0.2627
Q	120300	+50	102495	49.5622
	100250	+25	85500.5	24.7636
	60150	-25	51607.5	-24.6936
	40100	-50	34805	-49.2120
H	2.55	+50	102615	49.7373
	2.125	+25	85572.5	24.8687
	1.275	-25	51487.5	-24.8687
	0.85	-50	34445	-49.7373
S	45	+50	68710	0.2627
	37.5	+25	68620	0.1313
	22.5	-25	68440	-0.1313
	15	-50	68350	-0.2627

D. Computation for Item No. 4

The data for Transol 5%the key variables are taken with appropriate units as follows: D =843360 units/year, Q = 70280 units/order, H = 1.9 Rs. /unit, S = 35/lot size, daily demand d = 3373.44 units, and daily production rate p = 3400 units

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

$$Q_P^* = \sqrt{\frac{2 * 843360 * 35}{1.9[1\left(-\frac{3373.44}{3400}\right)]}}$$

Q_P^* =63067.3 Units

Total Cost $TC = \frac{D}{Q}S + \frac{Q}{2}H$

$$TC = \frac{843360}{70280}35 + \frac{70280}{2}1.9$$

$$TC = Rs. 67186$$

Table VIII. Sensitivity analysis for the key parameters of item no. 4

Parameter	Changes	Changes (in %)	Total Cost	Total Cost (in %)
D	1265040	+50	67396	0.3126
	1054200	+25	67291	0.1563
	316260	-25	67081	-0.1563
	421680	-50	66976	-0.3126
Q	105420	+50	100429	49..4791
	87850	+25	83793.5	24.7187
	17570	-25	50634.5	-24.6353
	35140	-50	34223	-49.0623
H	2.85	+50	100569	49.6874
	2.375	+25	83877.5	24.8437
	0.475	-25	50494.5	-24.8437
	0.45125	-50	33803	-49.6874
S	52.5	+50	67396	0.3126
	43.75	+25	67291	0.1563
	8.75	-25	67081	-0.1563
	17.5	-50	66976	-0.3126

E. Computation for Item No. 5

The data for Ciprosol Inf the key variables are taken with appropriate units as follows: D = 424200 units/year, Q =35350 units/order, H = 2.9 Rs. /unit, S = 48/lot size and, daily demand d = 1696.8 units, and daily production rate p = 1730 units

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

$$Q_P^* = \sqrt{\frac{2 * 424200 * 48}{2.9[1\left(-\frac{1696.8}{1730}\right)]}}$$

$$Q_P^* = 27050.5 \text{ Units}$$

$$\text{Total Cost } TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$TC = \frac{424200}{35350}48 + \frac{35350}{2}2.9$$

$$TC = Rs.51833.5$$

Table IX. Sensitivity analysis for the key parameters of item no. 5

Parameter	Changes	Changes (in %)	Total Cost	Total Cost (in %)
D	636300	+50	52121.5	0.5556
	530250	+25	51977.5	0.2778
	318150	-25	51689.5	-0.2778
	159075	-50	51545.5	-0.5556
Q	80025	+50	77270.25	49.0740
	66687.5	+25	64532.68	24.4999
	13337.5	-25	39211.125	-24.3518
	26675	-50	26780.75	-48.3331
H	4.35	+50	77462.25	49.4444
	3.625	+25	64647.875	24.7222
	2.175	-25	39019.125	-24.7222
	1.45	-50	26204.75	-49.4444
S	72	+50	52121.5	0.5556
	60	+25	51977.5	0.2778
	36	-25	51689.5	-0.2778
	24	-50	51545.5	-0.5556

F. Computation for Item No. 6

The data for Transol N/S the key variables are taken with appropriate units as follows: D = 676200units/year, Q =56350 units/order, H = 1.8 Rs. /unit, S = 27 Rs. /lot size, daily demand d = 2704.8 units, and daily production rate p = 2738 units

$$Q_P^* = \sqrt{\frac{2DS}{H[1\left(-\frac{d}{P}\right)]}}$$

$$Q_P^* = \sqrt{\frac{2 * 676200 * 27}{1.8[1\left(-\frac{2704.8}{2738}\right)]}}$$

$$Q_P^* = 40902.1 \text{ Units}$$

$$\text{Total Cost } TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$TC = \frac{676200}{56350}27 + \frac{56350}{2}1.8$$

$$TC = Rs. 51039$$

Table X. Sensitivity analysis for the key parameters of item no. 6

Parameter	Changes	Changes (in %)	Total Cost	Total Cost (in %)
D	1014300	+50	51201	0.3174
	845250	+25	51120	0.1587
	508150	-25	50958	-0.1587
	338100	-50	50877	-0.3174
Q	84525	+50	76288.5	49.4710
	70437.5	+25	63652.95	24.7143
	42262.5	-25	38468.25	-24.6297
	28175	-50	26005.5	-49.0478
H	2.7	+50	76396.5	49.6826
	2.25	+25	63717.75	24.8413
	1.35	-25	38360.25	-24.8413
	0.9	-50	25681.5	-49.6826
S	40.5	+50	51201	0.3174
	33.75	+25	51120	0.1587
	20.25	-25	50958	-0.1587
	13.5	-50	50877	-0.3174

V. RESULTS AND DISCUSSION

APL produces a total of 32 items. By using ABC analysis technique on the inventory items, they were classified in three classes A, B and C. Six items belongs to A class and 9 to class B and 17 to C. Class A items were taken for further analysis because both of them contributes to 80% cost monthly inventory cost. For these class A items the optimum production quantity Q_P^* was determined by using POQ model. After that the total cost was determined for each item. For example, the Q_P^* for item 1 which have registration number 62324 is as follow:

D= Average Total Monthly Demand = 80160*12 = 961920

d= Daily demand rate = 3847.68

p= daily production rate= 3855

H= Holding Cost= Rs. 2

S= Setup Cost = Rs. 40

Thus,

$$Q_P^* = \sqrt{\frac{2 * 961920 * 40}{2[1\left(-\frac{3847.68}{3855}\right)]}}$$

$$Q_P^* = 142349.6$$

Now the total Cost for this item

$$\text{Total Cost } TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$TC = \frac{961920}{80160}40 + \frac{80160}{2}2$$

$$TC = Rs. 80640$$

Similarly, it is done for the rest of fourteen items. After these calculations the sensitivity Analysis is performed so that we know the critical factor or variable with is more responsible for the increase or decrease of cost for the particular item. Sensitivity Analysis is performed by changing one variable and keeping all other variables fixed in the Cost equation.

VI. CONCLUSION

The proposed research develops the economic production quantity (EPQ) model for different items in Atlantic Pharmaceuticals Laboratories. The managers of Atlantic Pharmaceuticals Laboratories as well as of other industries of similar sectors will be benefited by the outcomes of the results as the optimal solution has been modelled in the most realistic manners. It is concluded from sensitivity analysis that holding cost (H) and quantity per order (Q) are the critical/sensitive parameters as compared to demand rate (D) and setup cost (S). The Effect of variable demand and setup cost are somehow same. Thus, by keeping holding cost and quantity per order in the right level the inventory can be controlled and reduced for each item cost up to 50% of the cost which is available in present time.

Furthermore, to check the influence of all parameter on the total cost, all parameters are manipulated separately. First of all demand is manipulated in a percentage so for 50% increase in demand the total cost is increased by 29.7%, and for 25% increase its influence is 14.8%. Similarly, for 50% decrease in demand has increased the total cost by -29.7% and for 25% decrease the total cost is decreased by -14.8%. Secondly, order quantity is manipulated in a percentage so for 50% increase in order quantity the total cost is increased by 49.5%, and for 25% increase its influence is 24.7%. Similarly, for 50% decrease in order quantity has increased the total cost by -49.1% and for 25% decrease the total cost is decreased by -24.6%.

Now, setup cost is manipulated in a percentage so for 50% increase in setup cost the total cost is increased by 29.7%, and for 25% increase its influence is 14.8%. Similarly, for 50% decrease in setup cost has increased the total cost by -29.7% and for 25% decrease the total cost is decreased by -14.8%. Further, holding cost is manipulated in a percentage so for 50% increase in holding cost the total cost is increased by 49.7%, and for 25% increase its influence is 24.8%. Similarly, for 50% decrease in holding cost has increased the total cost by -49.7% and for 25% decrease the total cost is decreased by 24.8%.

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