

## CASE STUDY

# Inventory planning for continuous demand materials – A case study in chip manufacturing industry

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Inventory is often a valuable asset of a business. Inventory planning is an important function in a manufacturing organization. Improper inventory planning can lead to excess inventory, increasing inventory costs, or lack of inventory, leading to reduced service levels. This article discusses planning inventory for continuous demand spare part materials for a company that assembles microprocessor chips. Spare part materials are classified according to ABC analysis; appropriate planning models for each type of material are used with the goals of minimizing inventory costs and satisfying a desired level of demand.

**Keywords:** inventory planning, working stock, safety stock, ABC analysis, fixed order size systems, EOQ, fixed order interval systems, EOI, multiple items EOI

## 1. Introduction

Inventory is a valuable asset of a business. The company under study is a microprocessor chip manufacturing company. The company's current inventory cost accounts for 60% of its total production cost. The company considers inventory planning an important function to help cut costs.

The factory operates continuously. The products, after going through the assembly process, will go to the most rigorous inspection steps. With regard to inspection machines, it should be ensured that there are enough spare parts for maintenance so as not to lead to the machine stopping; if the machine stops for a long time, it will lead to late delivery, affecting the company's service level.

Currently, the maintenance spare parts are not properly planned, leading to the situation that some maintenance spare parts are redundant, increasing inventory costs, some parts are missing, causing the machine to stop and leading to late delivery, and there is a low service level. From 2017 to 2020, out of a total of 990 requests for spare parts to serve testing machines, there are 170 shortages of spare parts. Therefore, the corresponding service level is as follows:

$$SL = \frac{(990 - 170)}{990} = 82.82 (\%)$$

The 82.82% service level is too low; the company wants to increase the service level to 95%. The company has 55 types of spare parts of continuous demand. This research undertakes the planning of these spare parts, with the objective of minimizing inventory costs and ensuring a desired level of service.

## 2. Research methodology

### 2.1. Inventory planning for continuous demand materials

Continuous demand inventories are those whose demand does not fluctuate much over time (1). Inventory planning is about answering two basic questions: when to order and how much to order. Planning models are used to answer these two basic questions. For high-value materials, the fixed order size model is often used. For average-value materials, the fixed order interval model is often used for each material. For low-value materials, the fixed order interval model for multiple items is often used.

Ferguson et al. (2) applied the EOQ model to inventory management of perishables. Nobil et al. (3) developed the reorder point for the EOQ inventory model with imperfect

quality items. Goh (4) constructed an EOQ model with general demand and holding cost functions. Mokhtari (5) developed EOQ for joint complementary and substitutable items. Sebatjane (6) developed an EOQ model for growing items with imperfect quality.

## 2.2. Research methodology

The materials under study are continuous demand materials that are planned according to the method of classifying materials by value and applying an appropriate model for each type of material (1). The planning process follows the following steps:

**Step 1: Classifying materials according to the ABC analysis.**

- Group A includes high-value materials, accounting for about 80% of the total inventory value.
- Group B includes average-value materials, accounting for about 15% of the total inventory value.
- Group C includes low-value materials, accounting for about 5% of the total inventory value.

**Step 2: Planning group A materials.**

Group A materials are planned according to the fixed order size FOS model, with the following two substeps:

- Planning lot size Q.
- Planning reorder points B.

Lot size Q is planned to minimize inventory costs, according to the economic order size EOQ model as follows:

$$Q = \sqrt{\frac{2CR}{H}} = \sqrt{\frac{2CR}{PF}}$$

where:

- R: annual demand (unit/year).
- P: purchase cost (\$/unit).
- C: order cost (\$/order).
- H: holding cost (\$/unit/year).
- F: holding coefficient (1/year).  $H = PF$

Reorder point B is planned to ensure the desired service level, based on the distribution of demand during lead time M. Reorder point B is determined as follows:

$$B = \mu + S = \mu + Z\sigma$$

where:

- S: safety stock
- Z: safety factor
- $\sigma$ : standard deviation of lead time demand M.
- $\mu$ : expected value of lead time demand M

Assuming lead time demand M has a normal distribution, safety factors Z are defined by service levels SL by **Table 1**.

**Step 3: Planning group B materials.**

Group B materials are planned according to the fixed order interval FOI model, with the following two substeps:

- Planning order interval T.

**TABLE 1 | Safety factors Z.**

SL (%)	90	91	92	93	94	95	96	97	98	99
Z	1.29	1.34	1.41	1.48	1.56	1.65	1.75	1.88	2.05	2.33

- Planning maximum inventory level E

The order cycle T is planned to minimize inventory costs, according to the economic order interval model EOI as follows:

$$T = \sqrt{\frac{2C}{HR}} = \sqrt{\frac{2C}{PFR}}$$

where:

- R: annual demand (unit/year).
- P: purchase cost (\$/unit).
- C: order cost (\$/order).
- H: holding cost (\$/unit/year).
- F: holding coefficient (1/year).  $H = PF$

The maximum inventory level E is planned to ensure the desired level of service, based on the distribution of demand over the total lead time and cycle time N. The maximum inventory level E is determined as follows:

$$E = \mu + S = \mu + Z\sigma$$

where:

- S: safety stock
- Z: safety factor
- $\sigma$ : standard deviation of N.
- $\mu$ : expected value of N.

Assuming N has a normal distribution, safety factors are defined by service levels by the above table.

**Step 4: Planning group C materials.**

Group C materials are planned according to the multiple-items fixed order interval model, MFOI, with the following two substeps:

- Planning order interval T for all items in the group.
- Planning maximum inventory level E for each item in the group.

The order cycle T is planned to minimize inventory costs, according to the multiple-items economic order interval model, MEOI, as follows:

$$T = \sqrt{\frac{2(C+nc)}{F \sum_{i=1}^n P_i R_i}}$$

where:

- n: total number of C-type materials.
- $R_i$ : annual demand of item i (unit/year).
- $P_i$ : purchase cost of item i (\$/unit).
- C: integrated order cost for all items (\$/order).
- c: partial order cost for each item (\$/order).
- F: holding coefficient (1/year).

The maximum inventory level  $E_i$  of material i is planned to ensure the desired service level, based on the distribution of

demand over the total lead time and cycle time  $N_i$  of material  $i$ . The maximum inventory level  $E_i$  is determined as follows:

$$E_i = \mu_i + S_i = \mu_i + Z\sigma_i$$

where:

- $S_i$ : safety stock of item  $i$ .
- $Z$ : safety factor.
- $\sigma_i$ : standard deviation of  $N_i$ .
- $\mu_i$ : expected valued of  $N_i$ .

Assuming  $N_i$  has a normal distribution, safety factors are defined by service levels by the above table.

### 3. ABC analysis for the company materials

The company has 55 continuous demand spare parts. Data of annual demand  $R$  and unit price  $P$  are collected, and total annual value  $RP$ , percent value  $PV$ , and cumulative percent value  $CPV$  are calculated as shown in **Table 2**, (7).

The table above shows that out of 55 continuous supplies, there are 31 group A materials, accounting for about 80% of the total inventory value, 15 group B materials accounting for about 15% of the total inventory value, and 9 group C materials, accounting for about 5% of total inventory value.

### 4. Inventory planning for A items

According to the above planning model, Group A materials are planned according to the FOS model. Among the 31 group A materials, P3TIU394 is selected for planning, and other materials are similarly planned.

#### 4.1. Lot size Q planning

Lot size  $Q$  is planned according to the following steps:

- Collect data and estimate parameters.
- Plan the lot size.

The parameters of the model include  $R$ ,  $P$ ,  $C$ , and  $H$ . The average annual demand  $R$  and unit purchase cost  $P$  of the material are collected as follows:

$$R = 850 (u/y)$$

$$P = 2259 (\$/u)$$

Order costs are analyzed into many components (8); these components are estimated as shown in **Table 3**. After the component costs are estimated, the order cost is estimated by summing these component costs.

The holding cost  $H$  can be estimated through the purchasing cost  $P$  and the holding coefficient  $F$ .

$$H = PF$$

**TABLE 2 |** ABC analysis for the company materials.

i	Spare parts	R (u)	P (\$/u)	RP (\$)	PV (%)	CPV (%)	Group
1	P3TIU394	850	2259	1920150	4.68	4.68	A
2	P1TIU379	800	2259	1807200	4.40	9.08	
3	P18AP598	800	2255	1804000	4.39	13.47	
4	P18TIU378	210	8576.26	1801015	4.39	17.86	
5	P28TIU344	200	8576.26	1715252	4.18	22.04	
6	P3TIU348	760	2250	1710000	4.16	26.2	
7	P44TESTER122	300	5091.94	1527582	3.72	29.92	
8	P18TESTER191	290	5091.94	1476663	3.60	33.52	
9	P1TESTER125	280	4968.81	1391267	3.39	36.91	
10	P18TIU371	500	2695	1347500	3.28	40.19	
11	P3TESTER102	300	4308.72	1292616	3.15	43.34	
12	P1TIU360	155	7871.2	1220036	2.97	46.31	
13	P44TIU301	300	4007.3	1202190	2.93	49.24	
14	P3TIU354	150	7871.2	1180680	2.88	52.12	
15	P1TESTER105	260	4308.72	1120267	2.73	54.85	
16	P28TESTER185	200	5091.94	1018388	2.48	57.33	
17	P28AP511	380	2490	946200	2.30	59.63	
18	P3TESTER175	160	4968.81	795010	1.94	61.57	
19	P18TIU376	60	13207.49	792449	1.93	63.5	
20	P1TIU400	350	2131.39	745987	1.82	65.32	
21	P3TIU362	50	13505.97	675299	1.64	66.96	
22	P28TIU357	50	13207.49	660375	1.61	68.57	
23	P44TIU388	50	13207.49	660375	1.61	70.18	
24	P1TESTER200	266	2478.26	659217	1.61	71.79	
25	P18TESTER190	50	11964.01	598201	1.46	73.25	
26	P28TIU320	230	2512.37	577845	1.41	74.66	
27	P44AP538	560	900	504000	1.23	75.89	
28	P28TESTER100	35	13830	484050	1.18	77.07	
29	P44TESTER165	35	13830	484050	1.18	78.25	
30	P18TESTER103	35	13830	484050	1.18	79.43	
31	P1HK620	1400	340	476000	1.16	80.59	
32	P18HK645	1400	340	476000	1.16	81.75	B
33	P44HK656	1400	340	476000	1.16	82.91	
34	P3TIU365	1000	450	450000	1.10	84.01	
35	P1TIU340	1000	450	450000	1.10	85.11	
36	P3HK677	1700	250	425000	1.03	86.14	
37	P3TESTER192	170	2478.26	421304	1.03	87.17	
38	P18TIU386	900	452	406800	0.99	88.16	
39	P44TESTER178	34	11964.01	406776	0.99	89.15	
40	P1AP554	200	2007	401400	0.98	90.13	
41	P44TIU376	180	2162	389160	0.95	91.08	
42	P3AP587	700	547.68	383376	0.93	92.01	
43	P28TIU390	160	2351.97	376315	0.92	92.93	
44	P28TESTER199	30	11964.01	358920	0.87	93.8	
45	P44TIU340	960	337.63	324125	0.79	94.59	
46	P44TIU302	1500	209	313500	0.76	95.35	
47	P1AP590	500	547.68	273840	0.67	96.02	C
48	P44TIU304	150	1782	267300	0.65	96.67	
49	P18TIU381	150	1662	249300	0.61	97.28	
50	P28HK691	600	400	240000	0.58	97.86	

(Continued)

**TABLE 2 |** (Continued)

i	Spare parts	R (u)	P (\$/u)	RP (\$)	PV (%)	CPV (%)	Group
51	P44TIU314	800	289	231200	0.56	98.42	
52	P1AP577	200	1112	222400	0.53	98.95	
53	P3AP582	190	1112	211280	0.5	99.45	
54	P28TIU385	300	621.6	186480	0.44	99.89	
55	P18TIU327	110	440	48400	0.11	100	
Total				41066787.8	100.00		

**TABLE 3 |** Estimation of order cost.

Cost components	Value (\$/order)	
Cost of finding suppliers	Search costs	20
	Contact costs	20
	Equipment cost	10
Costs to create orders	Paper and ink costs	4
	Phone costs	5
	Fax machine costs	4
	Printer cost	2
	Facility cost	10
	Software support costs	50
	Import and export costs	200
Receiving cost	Inspection cost	10
	Warehouse import cost	10
Labor costs	10	
Total	355	

**TABLE 4 |** Estimation of holding coefficient.

Cost components	Percentage	
Capital costs	Loan costs	5%
	Loss of capital opportunity	3%
Warehouse costs	Insurance	1%
	Tax	0%
	Machinery cost	1%
	Labor cost	0.5%
	Storage space costs	3%
Storage space costs	Company space costs	3%
	Outsourcing space costs	3%
	Risk and opportunity loss	1%
Risk and opportunity loss	Obsolete	1%
	Damage in storage	1%
	Shortage	1%
Total	20%	

The holding coefficient F is analyzed into many components (9); these components are estimated as shown in [Table 4](#). After the components are estimated, the holding coefficient is estimated by summing these components.

With the parameters estimated above, the optimal lot size of P3TIU394 is determined as follows:

$$Q^* = \text{EOQ} = \sqrt{\frac{2CR}{PF}} = \sqrt{\frac{2 \cdot 355 \cdot 850}{2259 \cdot 0.2}} = 36.55 \approx 37 \text{ (u)}$$

## 4.2. Reorder point planning

Reorder point B is planned according to the following steps:

- Collect data of service levels and lead time M.
- Estimate parameters Z,  $\mu$ , and  $\sigma$ .
- Plan safety stock S and reorder point B.

At a service level of 95%, the factor of safety is determined as follows:

$$Z = 1,64$$

Data of lead time demand M are collected; the expectation and standard deviation of M are estimated with the following results:

$$\mu = 153, \sigma = 16$$

Safety stock S and reorder point B are calculated as follows:

$$S = Z\sigma = 1,64 \times 16 = 26,24$$

$$B = \mu + S = 153 + 26,24 = 179,24$$

Collect data, estimate parameters, and do the same calculation for the remaining materials. Inventory plans for group A materials are all shown in [Table 5](#).

## 5. Inventory planning for B items

According to the above planning model, group B materials are planned according to the FOI model. Among the 15 group B materials, P18HK645 is selected for planning, and other materials are similarly planned (10).

### 5.1. Order interval T planning

Order interval T is planned according to the following steps:

- Collect data and estimate parameters.
- Plan the order interval T

The parameters of the model include R, P, C, and H. The average annual demand R and unit purchase cost P of the material are collected as follows:

$$R = 1400 \text{ (u/y)}$$

$$P = 340 \text{ ($/u)}$$

Similar to group A materials, the ordering cost of group B materials is estimated with the following results.

$$C = 355 (\$)$$

The holding cost H could be estimated by the holding cost factor F, which is estimated similar to the class A material above.

$$F = 20\%$$

With the above estimated parameters, the optimal ordering period of P18HK645 is determined as follows:

$$T^* = \sqrt{\frac{2C}{PFR}} = \sqrt{\frac{2 \times 355}{340 \times 0.2 \times 1400}} = 0.086 \text{ (year)} \approx 31 \text{ (day)}$$

### 5.2. Max inventory level E

The maximum inventory level E is planned according to the following steps:

- Collect data of service level SL and demand N.
- Estimate parameters Z,  $\mu$ , and  $\sigma$ .
- Plan safety stock S and maximum inventory E.

At the company's required service level of 95%, the factor of safety is defined as follows:

$$Z = 1,64$$

The demands in total lead time and cycle time N of P18HK645 are collected, from which the expected values and standard deviations are estimated as follows:

$$\mu = 309, \sigma = 11$$

The amount of safety stock and the maximum inventory level are calculated as follows:

$$S = Z\sigma = 1,64 \times 11 = 18,04$$

$$E = \mu + S = 309 + 18,04 = 327,04$$

Collect data, estimate parameters, and do the same calculation for the remaining materials. Inventory plans for group B materials are all shown in **Table 6**.

## 6. Inventory planning for C items

According to the above planning model, the nine class C materials are planned according to the MFOI model.

**TABLE 5 |** Inventory plans for group A materials.

i	Materials	R (u/y)	P (\$/u)	L (d)	Q (u)	B (u)
1	P3TIU394	850	2259	63	37	148
2	P1TIU379	800	2259	63	35	139
3	P18AP598	800	2255	63	35	139
4	P18TIU378	210	8576.26	133	9	77
5	P28TIU344	200	8576.26	133	9	73
6	P3TIU348	760	2250	35	35	73
7	P44TESTER122	300	5091.94	42	14	35
8	P18TESTER191	290	5091.94	42	14	34
9	P1TESTER125	280	4968.81	133	14	103
10	P18TIU371	500	2695	35	26	48
11	P3TESTER102	300	4308.72	133	16	110
12	P1TIU360	155	7871.2	42	8	18
13	P44TIU301	300	4007.3	42	16	35
14	P3TIU354	150	7871.2	42	8	17
15	P1TESTER105	260	4308.72	133	15	95
16	P28TESTER185	200	5091.94	42	12	23
17	P28AP511	380	2490	63	23	66
18	P3TESTER175	160	4968.81	133	11	59
19	P18TIU376	60	13207.49	42	4	7
20	P1TIU400	350	2131.39	42	24	40
21	P3TIU362	50	13505.97	42	4	6
22	P28TIU357	50	13207.49	42	4	6
23	P44TIU388	50	13207.49	42	4	6
24	P1TESTER200	266	2478.26	133	20	97
25	P18TESTER190	50	11964.01	98	4	13
26	P28TIU320	230	2512.37	42	18	27
27	P44AP538	560	900	56	47	86
28	P28TESTER100	35	13830	42	3	4
29	P44TESTER165	35	13830	42	3	4
30	P18TESTER103	35	13830	42	3	4
31	P1HK620	1400	340	56	121	216

### 6.1. Order interval T planning

Order interval T for all class C items is planned according to the following steps:

- Collect data and estimate parameters.
- Plan the order interval T.

The average annual demand  $R_i$  and unit purchase cost  $P_i$  of the materials are collected as shown in **Table 7**.

The integrated order cost C, the partial order cost c, and holding coefficient F are estimated as follows:

$$C = 889 \$/order, c = 355 \$/order, F = 20\%$$

The economic order cycle of all group C materials is calculated as follows:

$$T^* = \sqrt{\frac{2(C+nc)}{F \sum_{i=1}^n P_i R_i}} \sqrt{\frac{2(889+9*355)}{0.2*1930200}} = 0.1455 \text{ (y)} \approx 53 \text{ (d)}$$

**TABLE 6** | Inventory plans for group B materials.

i	Materials	P (\$/u)	R (u/y)	L (d)	T (d)	E (u)
1	P18HK645	340	1400	49	31	309
2	P44HK656	340	1400	56	31	337
3	P3TIU365	450	1000	63	32	262
4	P1TIU340	450	1000	56	32	243
5	P3HK677	250	1700	49	33	385
6	P3TESTER192	2478.26	170	133	33	78
7	P18TIU386	452	900	35	34	171
8	P44TESTER178	11964.01	34	98	34	12
9	P1AP554	2007	200	42	34	42
10	P44TIU376	2162	180	105	35	69
11	P3AP587	547.68	700	133	35	324
12	P28TIU390	2351.97	160	63	35	43
13	P28TESTER199	11964.01	30	98	36	11
14	P44TIU340	337.63	960	91	38	341
15	P44TIU302	209	1500	35	39	304

**TABLE 7** | Average annual demand  $R_i$  and unit purchase cost  $P_i$  of the materials.

i	Materials	$P_i$ (\$/u)	$R_i$ (u)	$P_i R_i$ (\$)
1	P1AP590	547.68	500	273,840
2	P44TIU304	1782	150	267,300
3	P18TIU381	1662	150	249,300
4	P28HK691	400	600	240,000
5	P44TIU314	289	800	231,200
6	P1AP577	1112	200	222,400
7	P3AP582	1112	190	211,280
8	P28TIU385	621.6	300	186,480
9	P18TIU327	440	110	48,400
Total				1,930,200

**TABLE 8** | Expected values and standard deviations of  $N_i$ .

i	Items	$\mu_i$	$\sigma_i$
1	P1AP590	258	11
2	P44TIU304	36	4
3	P18TIU381	39	4
4	P28HK691	167	10
5	P44TIU314	194	12
6	P1AP577	64	5
7	P3AP582	61	3
8	P28TIU385	95	9
9	P18TIU327	27	2

## 6.2. Max inventory level E

The maximum inventory level  $E_i$  of each material is planned according to the following steps:

**TABLE 9** | Safety stock and the maximum stock level of class C materials.

i	Items	S (u)	$E_i$ (u)
1	P1AP590	18	275
2	P44TIU304	7	43
3	P18TIU381	6	45
4	P28HK691	17	185
5	P44TIU314	19	213
6	P1AP577	9	73
7	P3AP582	5	66
8	P28TIU385	15	111
9	P18TIU327	4	31

- Collect data on service levels SL and demand  $N_i$ .
- Estimate the parameters  $Z$ ,  $\mu_i$ , and  $\sigma_i$ .
- Plan safety inventory  $S_i$  and maximum inventory level  $E_i$ .

At the company's required service level of 95%, the factor of safety is defined as follows:

$$Z = 1,64$$

The demand  $N_i$  of group C materials is collected, from which the expected values and standard deviations are estimated as shown in **Table 8**.

The amount of safety stock and the maximum stock level are calculated according to the following models.

$$S_i = Z\sigma_i$$

$$E_i = \mu_i + S_i$$

The calculation results are as shown in **Table 9**.

## 7. Conclusion

The article develops inventory plans for 55 spare parts that are in constant demand for a chip manufacturing company, with the goal of minimizing inventory costs and achieving a service level of 95%. ABC analysis divides these 55 spare parts into 31 Class A materials, 15 Class B materials, and 9 Class C materials.

The 31 Class A spare parts are planned under fixed lot size models. The 15 Class B spare parts are planned according to fixed order interval models. The 9 Class C spare parts are planned according to the fixed lot size model for multiple items.

The research has the advantage of applying operation research models to achieve cost objectives and service level requirement. But the downside is that demand distributions have not been determined, so the service level may not be as calculated. In addition, the study did not apply to evaluate actual effectiveness. Future research is to determine

demand distributions so that service levels can be accurately calculated. Research also needs to be applied in practice to evaluate its practical effectiveness.

## References

1. Nhu P. *Inventory Management*. HCM National University Press (2010).
2. Ferguson M, Jayaraman V, Souza G. An application of the EOQ model with nonlinear holding cost to inventory management of perishables. *Eur J Operat Res*. (2006) 180:485–90.
3. Nobil A, Amir Sedigh H, Cárdenas-Barrón L. Reorder point for the EOQ inventory model with imperfect quality items. *Ain Shams Eng J*. (2020) 11:1339–43.
4. Goh M. EOQ models with general demand and holding cost functions. *Eur J Operat Res*. (1994) 73:50–4.
5. Mokhtari H. Economic order quantity for joint complementary and substitutable items. *Math Comput Simul*. (2018) 154:34–47.
6. Sebatjane M. Economic order quantity model for growing items with imperfect quality. *Operat Res Perspect*. (2019) 6:88–90.
7. Adeyemi SL, Salami AO. Inventory management: a tool of optimizing resources in a manufacturing industry a case study of Coca-Cola bottling company Ilorin plant. *J Soc Sci*. (2010) 23:135–42.
8. Balan S. A case study on the determination of the economic order quantity for minimizing the inventory costs: model, analysis and insights. *Proceedings of the International Conference on Advances in Industrial Engineering Applications, Chennai, India, January 2010*. Chennai (2010).
9. Wikner C, Hammarström D. *Calculating Inventory Carrying Charge, Two Case Studies at Lantmännen*. University Thesis. Lund University of Technology (2010).
10. Hossain A, Hossain K, Das S. Joyanta Paul improved inventory management system for a jute mill - a case study. *J Mech Civil Eng*. (2013) 9:88–92.