CHAPTER 4
IMPLEMENTATION

4.1 ABC Analysis

The Italian economist Vilfredo Pareto represented 80/20 rule. It means 20 percents of items have 80% of value. The objective is to try to separate the important from the unimportant.

4.1.1 Steps in doing the ABC analysis are:

1. Determine the annual demand usage in each raw material
2. Multiply the annual demand usage of each raw material by the cost of the items to obtain the total annual Baht usage of each raw material.
3. Sum of annual cost of each raw material to get annual inventory expenditure
4. Take annual cost demand usage in each raw material divided by annual inventory expenditure to obtain the percentage of aggregate usage.
5. Rearrange raw material from highest percentage to lowest percentage
6. Review annual usage distribution and classify raw materials into class A, B, and C.

In this study, it has 28 raw materials in the regular color paints. These 28 raw materials are computed following these steps and shown in Table 4.1.

4.1.2 The concept to classify in each class is:

1. Class A items account for 10-20 percent of the item types and 60-80 percent of the total value of all items used.
2. Class B items account for 20-40 percent of the item types and 15-30 percent of the total value of all items used.
3. Class C items account for 50-60 percent of the item types and 5-10 percent of the total value of all items used.

Table 4.1: ABC analysis

Item	RW	Unit cost (Baht)	RM usage Year 02-03 (Kg)	Unit cost * RM usage	RM usage / total	Cumulative
1	RS-022	33	130468	4305444	0.2687	0.2687
2	HP-18	85	32929	2798965	0.1747	0.4433
3	M-50	250	9183	2295750	0.1433	0.5866
4	IP-820	34	33778	1148452	0.0717	0.6582
5	IP-333	1.5	514577	771865.5	0.0482	0.7064
6	IP-222	2.8	221836	621140.8	0.0388	0.7451
7	T-47/A	40	14640	585600	0.0365	0.7817
8	M-56	250	2320	580000	0.0362	0.8179
9	IP-555	2.3	200279	460641.7	0.0287	0.8466
10	M-10	225	1714	385650	0.0241	0.8707
11	IP-28	6	61380	368280	0.0230	0.8937
12	M-32	85	2964	251940	0.0157	0.9094
13	WDOR-100	550	435	239250	0.0149	0.9243
14	T-27	55	4198	230890	0.0144	0.9387
15	M-85	205	951	194955	0.0122	0.9509
16	M-92	110	1200	132000	0.0082	0.9591
17	M-75	58	1954	113332	0.0071	0.9662
18	WDYE-32	370	302	111740	0.0070	0.9732
19	LP-100	45	1824	82080	0.0051	0.9783
20	M-46	40	1986	79440	0.0050	0.9833
21	M-95	195	325	63375	0.0040	0.9872
22	M-87	50	1260	63000	0.0039	0.9911
23	WDYE-75	570	78	44460	0.0028	0.9939
24	WDCE-15	350	89	31150	0.0019	0.9959
25	M-48	12	2417	29004	0.0018	0.9977
26	WDYE-180	140	119	16660	0.0010	0.9987
27	WDBE-690	340	34	11560	0.0007	0.9994
28	WDBK-50	100	92	9200	0.0006	1.0000
Total				16025825		

These raw materials are classified into class A, B, and C that shown in Table 4.2 and the Figure 4.1 shows the figure of Class A, B, and C in the inventory.

Table 4.2: ABC Grouping

Class	Items	% Of total value	% Of total Quantity
A	1, 2, 3, 4, 5	70.64	17.85
B	6, 7, 8, 9, 10, 11, 12	20.3	25
C	13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28	9.06	57.14

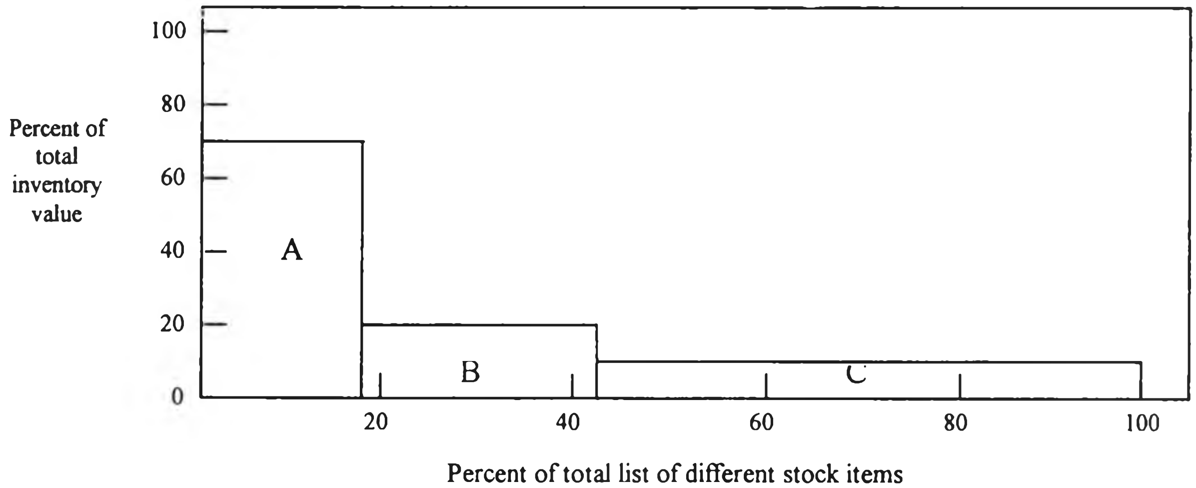

Figure 4.1: ABC Inventory Classification

Class A is the smallest percentage (17.85%) in their inventory but it has a large impact (70.64%) on the organisation. Therefore class A should be as low as possible, and safety stocks minimized because it is the important items. Moreover, an organisation must be concentrated closely.

Class B items receive an intermediate amount of attention. It has 25% of items, represented 20.3% of inventory value.

Class C is less impacted to inventory value (9.06%) so an organisation can sometimes be maintained with larger safety stocks because an organisation is not necessary to monitored it.

4.2 Method of Forecasting

A forecast is the method to predict what will occur in the future. An organisation is important to know the future prediction because an organisation can prepare its own behavior for meet the future demand that uncertainty.

4.2.1 Judgment Needed in Forecasting

Judgment is the special skill in decision-making that related with the evidence of key inputs—information, analysis, experience, and informed judgment. Normally, graph is the based pattern for judgment and selecting the method for forecasting. Some of the characteristics of forecasting based on these types of forecasts are shown in Table 4.3.

From Table 4.3, an organisation must be considered the factors to decide which range is suitable for the organisation to predict the demand forecasting. These factors are time frame, demand behavior, cost and accuracy, data available, and nature of products.

1. Time Frame

An organisation has to decide the time horizon or time frame to forecast. To decide the time horizon, it depends on many factors, for example, what data that an organisation has; how long an organisation wants to forecast; the situation of organisation for support forecasting. Time horizons, generally, are classified into three forecasting time horizons: short range, intermediate range, and long range.

In this study, an industry choose time frame in intermediate range because an industry wants to forecast a year for control the inventory. Therefore, from Table 4.3, the application is aggregate planning in term of inventory control. This is the industry objective. After an organisation knows the range, forecast method is the next step to decide which method is the most suitable for our organisation.

Table 4.3: Types and Characteristics of Forecasts

Range of Forecast	Representative horizon, or time	Applications	Characteristics	Forecast Methods
Long	Generally up to 5 years or more	Business planning: Product planning Research programming Capital planning Plant location and expansion	Broad, general Often only qualitative	Technological Economic Demographic Marketing studies Judgment
Intermediate	Generally up to 1 season to 2 years	Aggregate planning: Capital and cash budgets Sales planning Production planning Production and inventory budgeting	Numerical Not necessarily at the item level Estimate of reliability needed	Collective opinion Time series Regression Economic index correlation or combination Judgment
Short	Generally less than 1 season; 1 day to 1 year	Short-run control: Adjustment of Production and employment levels Purchasing Job scheduling Project assignment Overtime decisions	May be at item level for planning of activity level Should be at item level for adjustment of purchases and inventory	Trend extrapolation Graphical Explosion of short-range product or product family forecasts Judgment Exponential smoothing

2. Demand Behavior

Demand behavior is the characteristic of historical demand that separated into three types: trend, cycle, and seasonal pattern.

In this study, the demand behavior is the seasonal pattern. Seasonal pattern is an oscillating movement in demand that occurs periodically then repeat it again in the next period. Seasonal pattern is shown in Figure 4.2.

From figure 4.2, it shows the demand pattern of raw material RS-022 from Class A. Observe that it's composed of a loop in each year. Month 1 to month 6 and month 13 to month 18 are high demand seasons, and month 7 to month 12 and month 19 to month 24 are low demand seasons. For the other raw materials, the pattern is also the same as RS-022 due to the others raw materials are the components of color paint so the ratio usage is quite the same.

3. Cost and Accuracy

Cost and accuracy are the other way for decision to choose the method of forecasting because there may be a trade-off between cost and accuracy. It means high-accuracy approaches use more data, the data may difficult to obtain, so the model may be costly to design, implement, and operate. Therefore it depends on the situation of an industry and industrial policy.

4. Data Available

Data available is the one factor that important to choose forecasting method. It depends on the data relevant and correctible. In this study, the data identify seasonal pattern from the past data that shown in Figure 4.2.

5. Nature of Products

Nature of products, it effects to choose the method for forecasting. It depends on the type of product, volume, cost, or product life cycle. The products of this factor are the color paints that composed of many chemical raw materials and all raw materials have long life cycle and take a long time for shelf life occurring (may be a year) so an organisation doesn't concern about perishable.

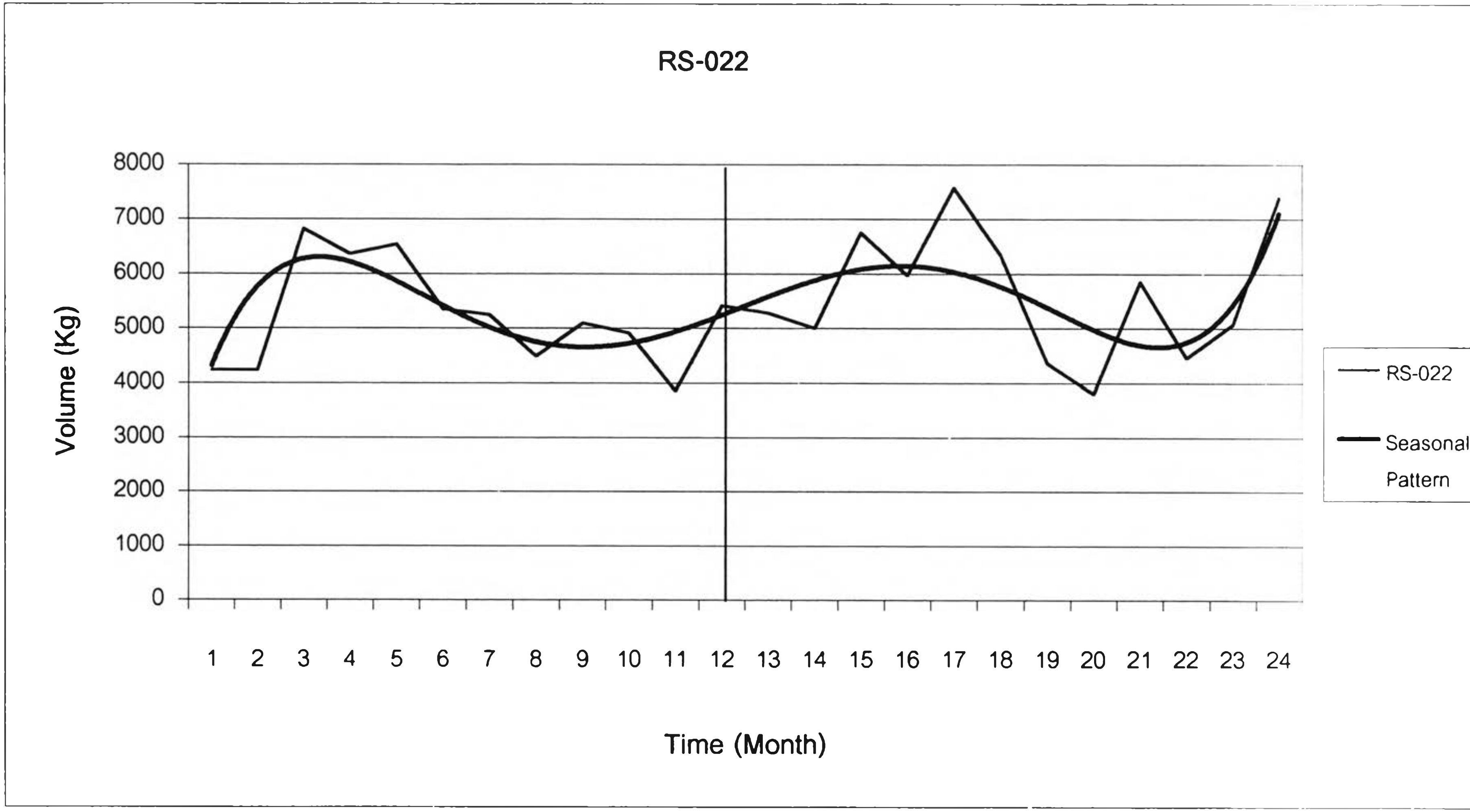

Figure 4.2: Demand pattern of raw material RS-022

4.2.2 Types of forecasting

Forecasting, normally, can be classified into four types that are qualitative, time series analysis, causal relationships, and simulation. In this study, it focuses on the type of causal model and time series based on seasonal pattern because it is based on the data relating between the expenditure of construction in Thailand and demand usage. Moreover, the components of time series are divided into four components: trend, seasonal, cyclical, and random component. Time series are separated into two time series models. It is time series smoothing and time series decomposition.

Therefore an industrial selected the model of time-series decomposition in seasonal pattern because figure 4.2 identifies that demand usage covered in two years and expressed in seasonal pattern.

4.2.2.1 Time series decomposition

Time series decomposition is more appropriate for seasonal demand pattern. It can be used when the general trend in the demand pattern is horizontal. When demand has both seasonal and trend effects at the same time, the question is how to solve it. Time series decomposition has two types to examine: additive and multiplicative.

The components to judge this demand usage is time series decomposition with a linear trend process:

1. Demand of raw material pattern is seasonal pattern
2. A trend is moving upward
3. Range between highest peak and lowest peak is not constant

4.2.2.2 Causal model

It is the time series models that have two or more variables related. Normally, one variable is independent demand (predictor) and another one is dependent demand. In this study, independent demand is the construction expenditure of Thailand and dependent demand is raw material usage.

Therefore this raw material is the seasonal component with a linear trend process because the graph is followed in these concepts to judgment. So an organisation can conclude that the demand usage should be used forecasting method in section of time series decomposition in method of multiplicative seasonal model and method of causal model.

4.2.3 Forecasting variables

In time series decomposition with linear trend process, it requires at least two years demand usage. Table 4.4 shows the demand usages in quarterly of 28 raw materials. Table 4.5 shows the construction expenditure of Thailand.

Table 4.4: Demand usage of all raw materials in two years

Item and Class	1A	2A	3A	4A	5A	6B	7B	8B
Raw Materials	RS-022	HP-18	M-50	IP-820	IP-333	IP-222	T-47/A	M-56
Quarterly								
Q1-02	15304	3875	1068	4001	59769	25870	1717	270
Q2-02	18255	4618	1277	4758	71508	30909	2048	331
Q3-02	14838	3779	1019	3948	56893	24833	1664	261
Q4-02	14188	3611	976	3769	54504	23770	1591	248
Q1-03	17036	4278	1215	4342	68238	29201	1913	304
Q2-03	19899	4997	1419	5072	79702	34107	2234	363
Q3-03	14024	3522	1000	3574	56174	24038	1575	242
Q4-03	16924	4250	1207	4314	67789	29009	1900	302

Table 4.4: Demand usage of all raw materials in two years (Continued)

Item and Class	9B	10B	11B	12B	13C	14C	15C	16C
Raw Materials	IP-555	M-10	IP-28	M-32	WDOR-100	T-27	M-85	M-92
Quarterly								
Q1-02	23211	200	7113	346	45	493	111	141
Q2-02	27788	239	8516	414	70	588	133	168
Q3-02	22000	192	6741	333	40	480	107	138
Q4-02	21085	184	6461	319	35	459	102	132
Q1-03	26651	226	8169	389	62	547	125	156
Q2-03	31129	263	9541	455	86	639	146	182
Q3-03	21940	186	6725	321	37	450	103	128
Q4-03	26476	224	8115	387	61	543	124	155

Table 4.4: Demand usage of all raw materials in two years (Continued)

Item and Class	17C	18C	19C	20C	21C	22C	23C	24C
Raw Materials	M-75	WDYE-32	LP-100	M-46	M-95	M-87	WDYE-75	WDCE-15
Quarterly								
Q1-02	227	32	214	235	38	148	8	6
Q2-02	271	48	255	280	46	176	13	9
Q3-02	218	28	207	232	38	143	7	4
Q4-02	209	24	198	222	36	137	6	4
Q1-03	255	43	239	255	42	165	11	8
Q2-03	298	59	279	298	49	192	16	11
Q3-03	210	26	196	210	34	136	6	5
Q4-03	253	42	237	254	41	164	11	7

Table 4.4: Demand usage of all raw materials in two years (Continued)

Item and Class	25C	26C	27C	28C
Raw Materials	M-48	WDYE-180	WDBE-690	WDBK-50
Quarterly				
Q1-02	282	12	4	10
Q2-02	337	21	5	15
Q3-02	271	10	3	8
Q4-02	259	8	3	7
Q1-03	318	18	5	13
Q2-03	372	27	7	18
Q3-03	262	9	3	8
Q4-03	316	17	5	13

Table 4.5: Construction expenditure

Quarter	Construction (Million Baht)
Q1-02	217,092
Q2-02	231,194
Q3-02	275,690
Q4-02	178,998
Q1-03	215,132
Q2-03	241,078
Q3-03	305,494
Q4-03	214,686
Q1-04e	225,000
Q2-04e	250,000
Q3-04e	320,000
Q4-04e	216,000

(**Source:** National Economic and Social Development Board)

4.2.4 Forecasting Process

Due to the information of expenditure construction is calculated in quarterly so the forecasting of Class A, B, and C has to forecast in quarterly too.

Steps to forecast in this model:

These steps will show only raw material RS-022 that shown in Table 4.6 but the rests of raw materials shows in Appendix A.

1. Compute a series of eight-period moving averages because there are eight quarters. Then associate each with the midpoint of the time periods averaged. So the average of periods 1-4 is 15646.25 kg, and put it in the point in time 6.5 in column moving average because the number of quarters is even.
2. Average successive pairs of moving averages to get centered moving averages and put it on the centered actual time periods in next column (e.g. average the moving averages associated with times 6.5 and 7.5 to obtain the centered moving average at time 7: ((15646.25+16079.25) /2 = 15862.75)
3. Find the seasonal ratios by using the actual time series value divided by the centered moving average at that point (e.g. 14838/15862.75 = 0.94)

4. Average the corresponding ratios in column seasonal ratio to obtain the seasonal factors (c_s). In this forecasting is covered in two year, it has only one number in each season ratio so that number is the seasonal factors. But the sum of seasonal factors (4 factors) equals 4.04 that rather than 4 so scale the seasonal factors by multiplying them by (4/4.04).
5. Using the actual demand usage divided by seasonal factor (c_s) to obtain the deseasonalized data in next column.
6. Using linear regression method on the deseasonalized data to obtain variables a and b.

   Therefore:

$$b = \frac{8(3059898679\ 9) - (1879364\ )(130855\ )}{8(4524419043\ 44) - (1879364\ )^2} = -0.013$$

$$a = [(130855)/8] - b[(1879364)/8] = 19397.075$$

   The linear trend forecasting modei with multiplicative seasonality is then given by:

$$F_t = [19397.075 - 0.013t]c_s$$

7. The forecasts result is shown in Table 4.7

Table 4.6: Deseasonalizing raw material of RS-022

Quarter	Construction Expenditure	Actual	Moving Average	Centered M.A.	Seasonal Ratio	Deseasonalized Data
Q1-02	217092	15304				14870
Q2-02	231194	18255	15646.25			15407
Q3-02	275690	14838	16079.25	15862.75	0.94	16021
Q4-02	178998	14188	16490.25	16284.75	0.87	16448
Q1-03	215132	17036	16286.75	16388.50	1.04	16552
Q2-03	241078	19899	16970.75	16628.75	1.20	16795
Q3-03	305494	14024				15142
Q4-03	214686	16924				19619
	c1 = 1.04	= 1.04*(4/4.04) =	1.03			

	c2 = 1.20	= 1.20*(4/4.04) =	1.18
	c3 = 0.94	= 0.94*(4/4.04) =	0.93
	c4 = 0.87	= 0.87*(4/4.04) =	0.86
Total	4.04		4.00

Table 4.7: Forecasting results of raw material RS-022 (A)

Quarter	Construction Expenditure	Forecast
Q1-04e	225000	16953.34
Q2-04e	250000	19131.28
Q3-04e	320000	14111.63
Q4-04e	216000	14310.04

For the rest of raw materials, the results of forecasting demand usage are shown in Table 4.8

Table 4.8: Forecasting results of the rests of raw materials

Item and Class	1A	2A	3A	4A	5A	6B	7B	8B
Raw Materials	RS-022	HP-18	M-50	IP-820	IP-333	IP-222	T-47/A	M-56
Quarterly								
Q1-04e	16953.34	4361.97	1159.75	4298.08	67935.99	29105.33	2007.95	367.46
Q2-04e	19131.28	4948.39	1294.28	4877.83	76187.39	32737.28	2280.73	432.29
Q3-04e	14111.63	3696.92	930.98	3621.87	55672.79	24038.67	1717.41	326.54
Q4-04e	14310.04	3718.89	951.84	3755.86	55385.45	24103.78	1688.81	301.45

Table 4.8: Forecasting results of the rest of raw materials (Continued)

Item and Class	9B	10B	11B	12B	13C	14C	15C	16C
Raw Materials	IP-555	M-10	IP-28	M-32	WDOR-100	T-27	M-85	M-92
Quarterly								
Q1-04e	26539.40	260.63	8109.61	450.42	92.67	551.39	121.78	161.84
Q2-04e	29722.69	297.44	9077.84	517.12	122.20	624.18	136.64	183.85
Q3-04e	21672.54	230.52	6611.15	400.78	66.72	463.55	99.57	138.36
Q4-04e	21465.48	214.44	6558.44	373.00	53.90	468.11	101.09	138.18

Table 4.8: Forecasting results of the rest of raw materials (Continued)

Item and Class	17C	18C	19C	20C	21C	22C	23C	24C
Raw Materials	M-75	WDYE-32	LP-100	M-46	M-95	M-87	WDYE-75	WDCE-15
Quarterly								
Q1-04e	248.6	39.44	233.63	260.34	50.72	169.23	17.96	8.88
Q2-04e	279.32	47.81	262.70	296.84	58.99	190.91	24.87	11.39
Q3-04e	203.43	20.93	191.85	223.19	46.75	142.91	12.72	5.09
Q4-04e	207.3	23.25	196.48	227.78	43.34	142.29	10.05	4.70

Table 4.8: Forecasting results of the rest of raw materials (Continued)

Item and Class	25C	26C	27C	28C
Raw Materials	M-48	WDYE-180	WDBE-690	WDBK-50
Quarterly				
Q1-04e	321.67	31.23	6.96	19.13
Q2-04e	363.06	44.03	9.23	24.86
Q3-04e	268.04	20.08	4.85	13.05
Q4-04e	266.35	14.46	4.42	10.65

4.3 Inventory Control with Limited Area

4.3.1 Selecting Models

Generally, inventory system is classified into two types that are fixed-order quantity models (Q model) and fixed-time period models (P-model). The objective of inventory models is developing policies in the moment to policies that suitable for the situation of the factory.

From ABC analysis, all raw materials are separated into three classes. First class is group A that is the most important to inventory value. Second class is group B that moderate important and the last class is group C that less important. Therefore group A should be concentrated the most. For group B, it should be concentrated generally. For group C, it should be less concentrated.

Therefore we decided to focus on group A and B in fixed-order quantity models because these two groups give 90.94% (70.64+20.3) of total inventory with 42.85% (17.85+25) of total quantity. The reasons for using this model because an industry has to concentrate for checking the level of inventory and keep record all the time. For the last group (group C), it suitable for the fixed-time period model because this model is less concentrate than fixed-order quantity model and, moreover, it keeps record only at review period.

4.3.2 Define Inventory Costs

Before developing inventory control, the costs are the main factors to control the inventory. The main costs that have an influent to inventory control are holding costs, stockout or shortage costs, and ordering or setup costs.

4.3.2.1 Holding costs

Holding cost is the costs of carrying items in inventory that come from the holding cost rate multiply by unit cost (unit cost in each raw material is shown in Table 4.1). The holding cost in this warehouse can be estimated from:

1. *Capital costs:* it is the money that invested in inventory and not available for use in the other areas. This cost is approximately 12% of inventory value.
2. *Storage costs:* this inventory belongs to the factory, not rented and leased so the storage costs is depended on depreciation, property taxes, insurance, or utilities. These costs are approximately 3% of the inventory value.

3. *Service costs:* these costs are the assessments and processing costs. The assessments are consisted of inventory taxes and insurance. The processing costs are consisted of materials handling and physical inventory. Therefore service costs are about 5% of inventory control.
4. *Risk costs:* it is the costs of obsolescence and shrinkage. The shrinkage costs are consisted of pilferage, disappearance, damage, spoilage, and devaluation of selling. These costs are approximately 3% of inventory value.

From these components, it can estimate the holding costs rate that is **23%** of inventory value.

4.3.2.2 Stockout costs

It is the costs when raw materials are not enough to demand. In a factory, stockout costs never kept in record but a manager defined the risk of each raw material equal to 2% in a year.

4.3.2.3 Ordering costs

It is the costs when order the items per one time. Ordering costs are consisted of cost of process, accessories cost, and working cost of operators. Table 4.9 shows the components of ordering cost.

Table 4.9 Components of ordering cost in this factory

Man hours in ordering process	Activities	Time usage
	Counting items	10 min
	Requisition order to purchase department	30 min
	Prepare purchase order	30 min
	Sending purchase order	10 min
	Receiving items	4 hr
	Move items to storage	2 hr
	Total	7 hr 20 min
Accessories cost (Baht)		Baht
	Document costs in ordering process e.g. sending/receiving form, record keeping form, etc.	50 Baht
	Other costs--cost of telephone, copies, fax, etc.	100 Baht
	Total	150 Baht
Salary of operators		Baht/month
	2 workers	9000
	4 officers	40000
	Total Average Salary per person (Baht/person)	8170

From table 4.9, the working days of this factory are 6 days per week and eight working hours per day (08.00am – 05.00pm) excluded lunchtime. Thus, cost per hour of operators is:

$$\cos t \ per \ hour = \frac{8170}{26 * 8} = 39.29 \approx 40 \ Baht \,/\, hour$$

Total time of ordering process is 7 hours and 20 minutes or 7.33 hours. So the working costs are 7.33 * 40 = 293.2 Baht.

Therefore the ordering costs are working costs plus accessories costs that equal to 293.2 + 150 = 443.2 or around **443 Baht per order**.

4.3.3 Fixed-Order Quantity Models (Q Model)

4.3.3.1 Economic Order Quantity (EOQ)

Economic order quantity is model for control the order quantity in each period of time. In this study, we assumed that:

1. Demand uncertainty but leadtime constant.
2. The cost factors do not change over time, in particular, inflation rate.
3. The replenishment time is equal to leadtime.
4. All raw materials keep in the same storage.

In this section, economic order quantity use for calculation in group A and B. Observe that the graphs demand pattern in these groups are similarity (see the figure 4.2 for raw material RS-022). The graph identifies that in each year demand usage has two seasons: high season and low season.

For high season, it occurred at the beginning of a year or quarter 1 to quarter 2, and for low season is in quarter 3 to quarter 4. Therefore, we decide to separate the EOQ into two values: first value in high season and second value in low season. The reason to calculate EOQ in two values in a year because an industry will not keep high stock through the year and protect the demand shortage in high season and overstock in low season.

The EOQ equation is:

$$EOQ = \sqrt{\frac{2C_oD}{C_h}}$$

where EOQ = Economic order quantity (units per order)

D = Forecasting demand usage in 2 quarters (6month) (kg) (Table 4.4 shows the forecasting demand usage in each raw material)

C_o = 443 Baht per order

C_h = unit cost (p)*holding cost rate (i) in 2 quarters (23% / 2)

Therefore EOQ in high demand season (EOQ_h) of raw material RS-022 is:

$$EOQ_h = \sqrt{\frac{2*443*36084.63}{33*0.115}} = 2902.5$$

EOQ in low demand season (EOQ_l) of raw material RS-022 is:

$$EOQ_l = \sqrt{\frac{2*443*28421.67}{33*0.115}} = 2575.94$$

(**Remark:** forecasting demands usage of raw material RS-022 is shown in Table 4.7)

Assumption: one pail of raw material RS-022 equals to 100 kg (Raw material size, see in Appendix B).

So purchasing department has to order RS-022 2902.5 kg/order or 29.02 pails/order in high demand season and order 2575.94 kg/order or 25.76 pails/order in low demand season.

Moreover, an organisation cannot order 29.02 pails or 25.76 pails so it has to using order discrete unit for decision.

Order discrete unit equation is:

$$Q' * (Q' - 1) \leq Q_0^2$$

For high season demand, EOQ is 29.02 pails so Q′ equals to 30 and Q′-1 equals to 29

$$30*29 \leq 29.02^2$$

$$870 \leq 842.16$$

So the number in left-hand side is greater than the number in right hand side, order 29 pails/order.

For low season demand, EOQ is 25.76 pails so Q′ equals to 26 and Q′-1 equals to 25

$$26*25 \leq 25.76^2$$

$$650 \leq 663.58$$

The number in left-hand side is less than the number in right hand side, order 26 pails/order.

Therefore, in high season demand, it will order 13 times (36084.63/2900) and, in low season demand, it will order 11 times (28421.67/2600).

For raw material HP-18, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*9130.36}{85*0.115}} = 909.71 \qquad EOQ_l = \sqrt{\frac{2*443*7415.81}{85*0.115}} = 819.86$$

Assumption: 1 bag / 25 kg

The purchasing department has to order HP-18 909.71 kg/order or 36.39 bags/order in high demand season and order 819.86 kg/order or 32.79 bags/order in low demand season.

When EOQ using order discrete unit, EOQ_h is 36 bags/order and EOQ_l is 33 bags/order.

Therefore, in high season demand, it will order 10 times (9130.36/(36*25)) and, in low season demand, it will order 9 times (7415.81/(33*25)).

For raw material M-50, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*2454.03}{250*0.115}} = 275.00 \qquad EOQ_l = \sqrt{\frac{2*443*1882.81}{250*0.115}} = 240.88$$

Assumption: 1 bag / 25 kg

The purchasing department has to order M-50 275 kg/order or 11 bags/order in high demand season and order 240.88 kg/order or 9.64 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 11 bags/order and EOQ_l equals to 10 bags/order.

Therefore, in high season demand, it will order 9 times and, in low season demand, it will order 8 times.

For raw material IP-820, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*9175.91}{34*0.115}} = 1441.96 \qquad EOQ_l = \sqrt{\frac{2*443*7377.73}{34*0.115}} = 1292.97$$

Assumption: 1 bag / 25 kg

The purchasing department has to order IP-820 1411.96 kg/order or 56.48 bags/order in high demand season and order 1292.97 kg/order or 51.72 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 56 bags/order and EOQ_l equals to 52 bags/order.

Therefore, in high season demand, it will order 7 times and, in low season demand, it will order 6 times.

For raw material IP-333, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*144123.38}{1.5*0.115}} = 27207.56 \qquad EOQ_l = \sqrt{\frac{2*443*111058.24}{1.5*0.115}} = 23883.49$$

Assumption: 1 bag / 25 kg and 1 pail / 500 kg

The purchasing department has to order IP-333 27207.56 kg/order or 1088.3 bags/order in high demand season and order 23883.49 kg/order or 955.34 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 1088 bags/order or 54 pails and 8 bags per order and EOQ_l equals to 955 bags/order or 47 pails and 15 bags per order.

Therefore, in high season demand, it will order 6 times and, in low season demand, it will order 5 times.

For raw material IP-222, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*61842.61}{2.8*0.115}} = 13044.66 \qquad EOQ_l = \sqrt{\frac{2*443*48142.45}{2.8*0.115}} = 11509.41$$

Assumption: 1 bag / 25 kg and 1 pail / 500 kg

The purchasing department has to order IP-222 13044.66 kg/order or 521.79 bags/order in high demand season and order 11509.41 kg/order or 460.38 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 522 bags/order or 26 pails and 2 bags per order and EOQ_l equals to 460 bags/order or 23 pails.

Therefore, in high season demand, it will order 5 times and, in low season demand, it will order 4 times.

For raw material T-47/A, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*4288.68}{40*0.115}} = 908.87 \qquad EOQ_l = \sqrt{\frac{2*443*3406.22}{40*0.115}} = 809.98$$

Assumption: 1 pail / 225 kg

The purchasing department has to order T-47/A 908.87 kg/order or 4.04 pails/order in high demand season and order 809.98 kg/order or 3.6 pails/order in low demand season.

From order discrete unit, EOQ_h equals to 4 pails/order and EOQ_l equals to 4 pails/order.

Therefore, in high season demand, it will order 5 times and, in low season demand, it will order 4 times.

For raw material M-56, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*799.75}{250*0.115}} = 157 \qquad EOQ_l = \sqrt{\frac{2*443*627.99}{250*0.115}} = 139.12$$

Assumption: 1 bag / 25 kg

The purchasing department has to order M-56 157 kg/order or 6.28 bags/order in high demand season and order 139.12 kg/order or 5.56 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 6 bags/order and EOQ_l equals to 6 bags/order.

Therefore, in high season demand, it will order 5 times and, in low season demand, it will order 4 times.

For raw material IP-555, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*56262.09}{2.3*0.115}} = 13728.15 \qquad EOQ_l = \sqrt{\frac{2*443*43138.02}{2.3*0.115}} = 12020.82$$

Assumption: 1 bag / 25 kg and 1 pail / 500 kg

The purchasing department has to order IP-555 13728.15 kg/order or 549.13 bags/order in high demand season and order 12020.82 kg/order or 480.83 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 549 bags/order or 27 pails/order and 9 bags/order and EOQ_l equals to 481 bags/order or 24 pails and 1 bag per order.

Therefore, in high season demand, it will order 4 times and, in low season demand, it will order 4 times.

For raw material M-10, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*558.07}{225*0.115}} = 138.24 \qquad EOQ_l = \sqrt{\frac{2*443*444.95}{225*0.115}} = 123.43$$

Assumption: 1 bag / 25 kg

The purchasing department has to order M-10 138.24 kg/order or 5.53 bags/order in high demand season and order 123.43 kg/order or 4.94 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 6 bags/order and EOQ_l equals to 5 bags/order.

Therefore, in high season demand, it will order 4 times and, in low season demand, it will order 4 times.

For raw material IP-28, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*17187.45}{6*0.115}} = 4697.84 \qquad EOQ_l = \sqrt{\frac{2*443*13169.59}{6*0.115}} = 4112.24$$

Assumption: 1 bag / 25 kg

The purchasing department has to order IP-28 4697.84 kg/order or 187.91 bags/order in high demand season and order 4112.24 kg/order or 164.49 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 188 bags/order and EOQ_l equals to 164 bags/order.

Therefore, in high season demand, it will order 4 times and, in low season demand, it will order 3 times.

For raw material M-32, EOQ is:

$$EOQ_h = \sqrt{\frac{2*443*967.55}{85*0.115}} = 296.14 \qquad EOQ_l = \sqrt{\frac{2*443*773.77}{85*0.115}} = 264.83$$

Assumption: 1 bag / 25 kg

The purchasing department has to order M-32 296.14 kg/order or 11.85 bags/order in high demand season and order 264.83 kg/order or 10.59 bags/order in low demand season.

From order discrete unit, EOQ_h equals to 12 bags/order and EOQ_l equals to 11 bags/order.

Therefore, in high season demand, it will order 3 times and, in low season demand, it will order 3 times.

These are the EOQ in each raw material of Class A and B. Table 4.10 shows the EOQ in each raw materials.

Table 4.10: EOQ of raw material in Class A and B.

Raw Material In Class A	EOQ		Raw Material In Class B	EOQ	
	High Season	Low Season		High Season	Low Season
RS-022	29 pails	26 pails	IP-222	26 pails and 2 bags	23 pails
HP-18	36 bags	33 bags	T-47/A	4 pails	4 pails
M-50	11 bags	10 bags	M-56	6 bags	6 bags
IP-820	56 bags	52 bags	IP-555	27 pails and 9 bags	24 pails and 1 bags
IP-333	54 pails and 8 bags	47 pails and 15 bags	M-10	6 bags	5 bags
			IP-28	188bags	164 bags
			M-32	12 bags	11 bags

4.3.3.2 Safety Stock (SS)

Safety stock is the spare items that using when demand over supply. The equation of safety stock is:

$$ss = z\sigma_L = z\sqrt{LT \cdot \sigma_d^2}$$

Assumption:

1. Demand usage is normal distribution
2. Leadtime is constant that equals to 2 days or 0.066 month
3. A manager defines the risk of stockout less than 2%
4. The value of sample standard deviation is the same as population standard deviation due to the limitation of collecting data

From the risk of stockout is less than 2%, from Appendix C, the area under normal distribution is 1-0.01 = 0.98 so z-value is 2.06

For raw material RS-022, safety stock is

$$ss = 2.06\sqrt{0.066\sigma_d^2}$$

Standard deviation of demand per period (σ_p) can be calculated from forecasting demand usage that shown in Table 4.11.

Table 4.11: Calculation of standard deviation of RS-022

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- \bar{a})^2$
Q1-04	16953.34	18042.31	-1088.97	1185857
Q2-04	19131.28	18042.31	1088.97	1185857
Total	**36084.63**			**2371714**
Average (ā)	18042.31			
Q3-04	14111.63	14210.83	-99.20	9841.043
Q4-04	14310.04	14210.83	99.21	9842.841
Total	**28421.67**			**19683.88**
Average (ā)	14210.83			

From Table 4.11, the standard deviation of demand in high seasonal period (σ_{ph}) is:

$$\sigma_{ph} = \sqrt{\frac{2371714}{2}} = 1088.97$$

And the standard deviation of demand in low seasonal period (σ_{pl}) is:

$$\sigma_{pl} = \sqrt{\frac{19683.88}{2}} = 99.21$$

Therefore safety stock of RS-022 in high seasonal period (SS_h) is

$$SS_h = 2.06\sqrt{0.066\,(1088.97^2)} \approx 576$$

And safety stock of RS-022 in low seasonal period (SS_l) is

$$SS_l = 2.06\sqrt{0.066\,(99.21^2)} \approx 53$$

An organisation should keep safety stock of RS-022 576 kg or 6 pails in high demand season and keep 53 kg or 1 pail in low demand season.

For raw material HP-18,

The calculation of standard deviation of demand is shown in Table 4.12

Table 4.12: Calculation of standard deviation of demand per period (σ_p) of HP-18

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	4361.97	4655.18	-293.21	85972.89
Q2-04	4948.39	4655.18	293.21	85972.89
Total	**9310.36**			**171945.79**
Average (ā)	**4655.18**			
Q3-04	3696.92	3707.90	-10.98	120.62
Q4-04	3718.89	3707.90	10.98	120.62
Total	**7415.81**			**241.24**
Average (ā)	**3707.90**			

The standard deviations of demand are:

$$\sigma_a = \sqrt{\frac{171945.79}{2}} = 293.21 \qquad \sigma_a = \sqrt{\frac{241.24}{2}} = 10.98$$

Therefore, safety stocks are:

$$ss_h = 2.06\sqrt{0.066(293.21^2)} \approx 155 \qquad ss_l = 2.06\sqrt{0.066(10.98^2)} \approx 6$$

An organisation should keep safety stock of HP-18 155 kg or 6 bags in high demand season and keep 6 kg or 1 bag in low demand season.

For raw material M-50,

The calculation of standard deviation of demand is shown in Table 4.13

Table 4.13: Calculation of standard deviation of demand per period (σ_p) of M-50

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a - \bar{a})^2$
Q1-04	1159.75	1227.01	-67.27	4524.93
Q2-04	1294.28	1227.01	67.27	4524.93
Total	2454.03			9049.85
Average (ā)	1227.01			
Q3-04	930.98	941.41	-10.43	108.79
Q4-04	951.84	941.41	10.43	108.79
Total	1882.81			217.57
Average (ā)	941.41			

The standard deviations of demand are:

$$\sigma = \sqrt{\frac{9049.85}{2}} = 67.27 \qquad \sigma = \sqrt{\frac{217.57}{2}} = 10.43$$

Therefore, safety stocks are:

$$ss = 2.06\sqrt{0.066\left(67.27^2\right)} \approx 36 \qquad ss = 2.06\sqrt{0.066\left(10.43^2\right)} \approx 6$$

An organisation should keep safety stock of M-50 36 kg or 2 bags in high demand season and keep 6 kg or 1 bag in low demand season.

For raw material IP-820,

The calculation of standard deviation of demand is shown in Table 4.14

Table 4.14: Calculation of standard deviation of demand per period (σ_p) of IP-820

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	4298.08	4587.96	-289.87	84026.19
Q2-04	4877.83	4587.96	289.87	84026.19
Total	9175.91			168052.39
Average (ā)	4587.96			
Q3-04	3621.87	3688.87	-67.00	4488.73
Q4-04	3755.86	3688.87	67.00	4488.73
Total	7377.73			8977.47
Average (ā)	3688.87			

The standard deviations of demand are:

$$\sigma_{a} = \sqrt{\frac{168052.39}{2}} = 289.87 \qquad \sigma_{a} = \sqrt{\frac{8977.47}{2}} = 67$$

Therefore, safety stocks are:

$$ss = 2.06\sqrt{0.066\left(289.87^{2}\right)} \approx 154 \qquad ss = 2.06\sqrt{0.066\left(67^{2}\right)} \approx 36$$

An organisation should keep safety stock of IP-820 154 kg or 7 bags in high demand season and keep 36 kg or 2 bags in low demand season.

For raw material IP-333,

The calculation of standard deviation of demand is shown in Table 4.15

Table 4.15: Calculation of standard deviation of demand per period (σ_p) of IP-333

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	67935.99	72061.69	-4125.70	17021377.27
Q2-04	76187.39	72061.69	4125.70	17021377.27
Total	144123.38			34042754.54
Average (ā)	72061.69			
Q3-04	55672.79	55529.12	143.67	20641.53
Q4-04	55385.45	55529.12	-143.67	20641.53
Total	111058.24			41283.06
Average (ā)	55529.12			

The standard deviations of demand are:

$$\sigma_h = \sqrt{\frac{34042754.54}{2}} = 4125.70 \qquad \sigma_l = \sqrt{\frac{41283.06}{2}} = 143.67$$

Therefore, safety stocks are:

$$ss_h = 2.06\sqrt{0.066\left(4125.70^2\right)} \approx 2183 \qquad ss_l = 2.06\sqrt{0.066\left(143.67^2\right)} \approx 76$$

An organisation should keep safety stock of IP-333 2183 kg or 4 pails and 8 bags in high demand season and keep 76 kg or 3 bags in low demand season.

For raw material IP-222,

The calculation of standard deviation of demand is shown in Table 4.16

Table 4.16: Calculation of standard deviation of demand per period (σ_p) of IP-222

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	29105.33	30921.30	-1815.98	3297772.98
Q2-04	32737.28	30921.30	1815.98	3297772.98
Total	61842.61			6595545.96
Average (ā)	30921.30			
Q3-04	24038.67	24071.23	-32.55	1059.83
Q4-04	24103.78	24071.23	32.55	1059.83
Total	48142.45			2119.65
Average (ā)	24071.23			

The standard deviations of demand are:

$$\sigma_h = \sqrt{\frac{6595545.96}{2}} = 1815.98 \qquad \sigma_l = \sqrt{\frac{2119.65}{2}} = 32.55$$

Therefore, safety stocks are:

$$ss_h = 2.06\sqrt{0.066\left(1815.98^2\right)} \approx 961 \qquad ss_l = 2.06\sqrt{0.066\left(32.55^2\right)} \approx 18$$

An organisation should keep safety stock of IP-222 961 kg or 1 pail and 19 bags in high demand season and keep 18 kg or 1 bag in low demand season.

For raw material T-47/A,

The calculation of standard deviation of demand is shown in Table 4.17

Table 4.17: Calculation of standard deviation of demand per period (σ_p) of T-47/A

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a - \bar{a})^2$
Q1-04	2007.95	2144.34	-136.39	18601.10
Q2-04	2280.73	2144.34	136.39	18601.10
Total	4288.68			37202.20
Average (ā)	2144.34			
Q3-04	1717.41	1703.11	14.30	204.44
Q4-04	1688.81	1703.11	-14.30	204.44
Total	3406.22			408.89
Average (ā)	1703.11			

The standard deviations of demand are:

$$\sigma_a = \sqrt{\frac{37202.2}{2}} = 136.39 \qquad \sigma_a = \sqrt{\frac{408.89}{2}} = 14.3$$

Therefore, safety stocks are:

$$ss_s = 2.06\sqrt{0.066\left(136.39^2\right)} \approx 73 \qquad ss_l = 2.06\sqrt{0.066\left(14.3^2\right)} \approx 8$$

An organisation should keep safety stock of T-47/A 73 kg or 1 pail in high demand season and keep 8 kg or one pail in low demand season.

For raw material M-56,

The calculation of standard deviation of demand is shown in Table 4.18

Table 4.18: Calculation of standard deviation of demand per period (σ_p) of M-56

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a-\bar{a})^2$
Q1-04	367.46	399.87	-32.42	1050.75
Q2-04	432.29	399.87	32.42	1050.75
Total	799.75			2101.50
Average (ā)	399.87			
Q3-04	326.54	313.99	12.55	157.39
Q4-04	301.45	313.99	-12.55	157.39
Total	627.99			314.78
Average (ā)	313.99			

The standard deviations of demand are:

$$\sigma_a = \sqrt{\frac{2101.5}{2}} = 32.42 \qquad \sigma_a = \sqrt{\frac{314.78}{2}} = 12.55$$

Therefore, safety stocks are:

$$ss = 2.06\sqrt{0.066\,(32.42^2)} \approx 18 \qquad ss = 2.06\sqrt{0.066\,(12.55^2)} \approx 7$$

An organisation should keep safety stock of M-56 18 kg or 1 bag in high demand season and keep 7 kg or 1 bag in low demand season.

For raw material IP-555,

The calculation of standard deviation of demand is shown in Table 4.19

Table 4.19: Calculation of standard deviation of demand per period (σ_p) of IP-555

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a-\bar{a})^2$
Q1-04	26539.40	28131.04	-1591.64	2533330.71
Q2-04	29722.69	28131.04	1591.64	2533330.71
Total	56262.09			5066661.42
Average (ā)	28131.04			
Q3-04	21672.54	21569.01	103.53	10718.87
Q4-04	21465.48	21569.01	-103.53	10718.87
Total	43138.02			21437.74
Average (ā)	21569.01			

The standard deviations of demand are:

$$\sigma_h = \sqrt{\frac{5066661.42}{2}} = 1591.54 \qquad \sigma_l = \sqrt{\frac{21437.74}{2}} = 103.53$$

Therefore, safety stocks are:

$$ss_h = 2.06\sqrt{0.066\,(1591.64^2)} \approx 849 \qquad ss_l = 2.06\sqrt{0.066\,(103.53^2)} \approx 56$$

An organisation should keep safety stock of IP-555 849 kg or 1 pail and 14 bags in high demand season and keep 56 kg or 3 bags in low demand season.

For raw material M-10,

The calculation of standard deviation of demand is shown in Table 4.20

Table 4.20: Calculation of standard deviation of demand per period (σ_p) of M-10

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- ā)^2$
Q1-04	260.63	279.04	-18.40	338.64
Q2-04	297.44	279.04	18.40	338.64
Total	558.07			677.27
Average (ā)	279.04			
Q3-04	230.52	222.48	8.04	64.64
Q4-04	214.44	222.48	-8.04	64.64
Total	444.95			129.27
Average (ā)	222.48			

The standard deviations of demand are:

$$\sigma_h = \sqrt{\frac{677.27}{2}} = 18.4 \qquad \sigma_l = \sqrt{\frac{129.27}{2}} = 8.04$$

Therefore, safety stocks are:

$$ss_h = 2.06\sqrt{0.066(18.4^2)} \approx 10 \qquad ss_l = 2.06\sqrt{0.066\,(8.04^2)} \approx 5$$

An organisation should keep safety stock of M-10 10 kg or one bag in high demand season and keep 5 kg or one bag in low demand season.

For raw material IP-28,

The calculation of standard deviation of demand is shown in Table 4.21

Table 4.21: Calculation of standard deviation of demand per period (σ_p) of IP-28

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- \bar{a})^2$
Q1-04	8109.61	8593.73	-484.12	234368.95
Q2-04	9077.84	8593.73	484.12	234368.95
Total	17187.45			468737.90
Average (ā)	8593.73			
Q3-04	6611.15	6584.80	26.35	694.48
Q4-04	6558.44	6584.80	-26.35	694.48
Total	13169.59			1388.95
Average (ā)	6584.80			

The standard deviations of demand are:

$$\sigma_a = \sqrt{\frac{468737.9}{2}} = 484.12 \qquad \sigma_a = \sqrt{\frac{1388.95}{2}} = 26.35$$

Therefore, safety stocks are:

$$ss_a = 2.06\sqrt{0.066\left(484.12^2\right)} \approx 258 \qquad ss_l = 2.06\sqrt{0.066\left(26.35^2\right)} \approx 14$$

An organisation should keep safety stock of IP-28 258 kg or 11 bags in high demand season and keep 14 kg or one bag in low demand season.

For raw material M-32,

The calculation of standard deviation of demand is shown in Table 4.22

Table 4.22: Calculation of standard deviation of demand per period (σ_p) of M-32

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- \bar{a})^2$
Q1-04	450.42	483.77	-33.35	1112.33
Q2-04	517.12	483.77	33.35	1112.33
Total	967.55			2224.66
Average (ā)	483.77			
Q3-04	400.78	386.89	13.89	192.90
Q4-04	373.00	386.89	-13.89	192.90
Total	773.77			385.81
Average (ā)	386.89			

The standard deviations of demand are:

$$\sigma_a = \sqrt{\frac{2224.66}{2}} = 33.35 \qquad \sigma_a = \sqrt{\frac{385.81}{2}} = 13.89$$

Therefore, safety stocks are:

$$ss_a = 2.06\sqrt{0.066\left(33.35^2\right)} \approx 18 \qquad ss_l = 2.06\sqrt{0.066\left(13.89^2\right)} \approx 8$$

An organisation should keep safety stock of M-32 18 kg or one bag in high demand season and keep 8 kg or one bag in low demand season.

These are the safety stock of Class A and B. Table 4.23 summaries the safety stock in Class A and B.

Table 4.23: Safety stock of Class A and B

Raw Material In Class A	Safety stock		Raw Material In Class B	Safety stock	
	High Season	Low Season		High Season	Low Season
RS-022	6 pails	1 pail	IP-222	1 pail and 19 bags	1 bag
HP-18	6 bags	1 bag	T-47/A	1 pail	1 pail
M-50	2 bags	1 bag	M-56	1 bag	1 bag
IP-820	7 bags	2 bags	IP-555	1 pail and 14 bags	3 bags
IP-333	4 pails and 8 bags	3 bags	M-10	1 bag	1 bag
			IP-28	11 bags	1 bag
			M-32	1 bag	1 bag

4.3.3.3 Maximum stock

Maximum stock is the highest level of that raw material inventory. It is the sum of economic order quantity (EOQ) and safety stock (SS). Table 4.24 shows the maximum stock level of each raw material of Class A and B.

Table 4.24: Maximum stock of Class A and B

Raw Material In Class A	EOQ		Safety stock		Maximum stock	
	High Season	Low Season	High Season	Low Season	High Season	Low Season
RS-022	29 pails	26 pails	6 pails	1 pail	35 pails	27 pails
HP-18	36 bags	33 bags	6 bags	1 bag	42 bags	34 bags
M-50	11 bags	10 bags	2 bags	1 bag	13 bags	11 bags
IP-820	56 bags	52 bags	7 bags	2 bags	63 bags	54 bags
IP-333	54 pails and 8 bags	47 pails and 15 bags	4 pails and 8 bags	3 bags	58 pails and 16 bags	47 pails and 18 bags

Table 4.24: Maximum stock of Class A and B (Continued)

Raw Material In	EOQ		Safety stock		Maximum stock	
Class B	High Season	Low Season	High Season	Low Season	High Season	Low Season
IP-222	26 pails and 2 bags	23 pails	1 pail and 19 bags	1 bag	28 pails and 1 bag	24 pails and 1 bag
T-47/A	4 pails	4 pails	1 pail	1 pail	5 pails	5 pails
M-56	6 bags	6 bags	1 bag	1 bag	7 bags	7 bags
IP-555	27 pails and 9 bags	24 pails and 1 bags	1 pail and 14 bags	3 bags	29 pails and 3 bags	24 pails and 4 bags
M-10	6 bags	5 bags	1 bag	1 bag	7 bags	6 bags
IP-28	188baqs	164 bags	11 bags	1 bag	199 bags	165 bags
M-32	12 bags	11 bags	1 bag	1 bag	13 bags	12 bags

4.3.3.4 Reorder point (RP)

Reorder point equals to the number of units used during the leadtime (demand during leadtime) plus safety stock. The equation of reorder point is:

$$RP = \bar{D}LT + SS$$

(**Note**: This demand average in each season equals to forecasting demand in 2 quarters divided by 6 months)

For raw material RS-022, reorder point in high season (RP_h) is:

$$RP_h = (6014.1 * 0.066) + (6 * 100) \approx 1003$$

Reorder point in low season (RP_l) of RS-022 is:

$$RP_l = (4736.95 * 0.066) + (1 * 100) \approx 418$$

Therefore, in high season, an organisation has to reorder raw material RS-022 when raw material on hand fall to 1003 Kg or 10 pails then order 29 pails. For low season, an organisation has to reorder when the stock on hand gets down to 418 kg or 4 pails, order 26 pails.

For raw material HP-18, reorder points are:

$$RP_h = (1551.73 * 0.066) + (6 \bullet 25) \approx 254 \qquad RP_l = (1235.97 * 0.066) + (1 \bullet 25) \approx 108$$

Therefore, in high season, an organisation has to reorder raw material HP-18 when raw material on hand fall to 254 Kg or 10 bags then order 36 bags. For low season, an organisation has to reorder when the stock on hand gets down to 108 kg or 4 bags, order 33 bags.

For raw material M-50, reorder points are:

$$RP_h = (409 * 0.066) + (2 \bullet 25) \approx 78 \qquad RP_l = (313.8 * 0.066) + (1 \bullet 25) \approx 46$$

Therefore, in high season, an organisation has to reorder raw material M-50 when raw material on hand fall to 78 Kg or 3 bags then order 11 bags. For low season, an organisation has to reorder when the stock on hand gets down to 46 kg or 2 bags, order 10 bags.

For raw material IP-820, reorder points are:

$$RP_h = (1529.32 * 0.066) + (7 \bullet 25) \approx 276 \qquad RP_l = (1229.62 * 0.066) + (2 \bullet 25) \approx 132$$

Therefore, in high season, an organisation has to reorder raw material IP-820 when raw material on hand fall to 276 Kg or 11 bags then order 56 bags. For low season, an organisation has to reorder when the stock on hand gets down to 132 kg or 6 bags, order 52 bags.

For raw material IP-333, reorder points are:

$$RP_h = (24020.56 * 0.066) + (4 \bullet 500 + 8 \bullet 25) \approx 3785$$

$$RP_l = (18509.7 * 0.066) + (3 \bullet 25) \approx 1297$$

Therefore, in high season, an organisation has to reorder raw material IP-333 when raw material on hand fall to 3785 Kg or 7 pails and 11 bags then order 54 pails and 8 bags. For low season, an organisation has to reorder when the stock on hand gets down to 1297 kg or 2 pails and 12 bags, order 47 pails and 15 bags.

For raw material IP-222, reorder points are:

$$RP_h = (10307.1 * 0.066) + (1 \bullet 500 + 19 \bullet 25) \approx 1655$$

$$RP_l = (8023.74 * 0.066) + (1 \bullet 25) \approx 555$$

Therefore, in high season, an organisation has to reorder raw material IP-222 when raw material on hand fall to 1655 Kg or 3 pails and 6 bags then order 26pails and 2 bags. For low season, an organisation has to reorder when the stock on hand gets down to 555 kg or 1 pails and 2 bags, order 23 pails.

For raw material T-47/A, reorder points are:

$$RP_h = (714.78 * 0.066) + (1 \bullet 225) \approx 272 \qquad RP_l = (567.7 * 0.066) + (1 \bullet 225) \approx 262$$

Therefore, in high season, an organisation has to reorder raw material T-47/A when raw material on hand fall to 272 Kg or 1 pail then order 4 pails. For low season, an organisation has to reorder when the stock on hand gets down to 262 kg or one pail, order 4 pails.

For raw material M-56, reorder points are:

$$RP_h = (133.29 * 0.066) + (1 \bullet 25) \approx 34 \qquad RP_l = (104.67 * 0.066) + (1 \bullet 25) \approx 32$$

Therefore, in high season, an organisation has to reorder raw material M-56 when raw material on hand fall to 34 kg or 2 bags then order 6 bags. For low season, an organisation has to reorder when the stock on hand gets down to 32 kg or 2 bags, order 6 bags.

For raw material IP-555, reorder points are:

$$RP_h = (9377.01 * 0.066) + (1 \bullet 500 + 14 \bullet 25) \approx 1469 \qquad RP_l = (7189.67 * 0.066) + (3 \bullet 25) \approx 550$$

Therefore, in high season, an organisation has to reorder raw material IP-555 when raw material on hand fall to 1469 Kg or 2 pails and 19 bags then order 27 pails and 9 bags. For low season, an organisation has to reorder when the stock on hand gets down to 550 kg or 1 pail and 2 bags, order 24 pails and 1 bag.

For raw material M-10, reorder points are:

$$RP_h = (93.01 * 0.066) + (1 \bullet 25) \approx 31 \qquad RP_l = (74.16 * 0.066) + (1 \bullet 25) \approx 30$$

Therefore, in high season, an organisation has to reorder raw material M-10 when raw material on hand fall to 31 kg or 1 bag then order 6 bags. For low season, an organisation has to reorder when the stock on hand gets down to 30 kg or 1 bag, order 5 bags.

For raw material IP-28, reorder points are:

$$RP_h = (2864.58 * 0.066) + (11 \bullet 25) \approx 464 \qquad RP_l = (2194.93 * 0.066) + (1 \bullet 25) \approx 170$$

Therefore, in high season, an organisation has to reorder raw material IP-28 when raw material on hand fall to 464 kg or 19 bags then order 188 bags. For low season, an organisation has to reorder when the stock on hand gets down to 170 kg or 7 bags, order 164 bags.

For raw material M-32, reorder points are:

$$RP_h = (161.26 * 0.066) + (1 \bullet 25) \approx 36 \qquad RP_l = (128.96 * 0.066) + (1 \bullet 25) \approx 34$$

Therefore, in high season, an organisation has to reorder raw material M-32 when raw material on hand fall to 36 kg or 2 bags then order 12 bags. For low season, an organisation has to reorder when the stock on hand gets down to 34 kg or 2 bags, order 11 bags.

All of these are the reorder point of each raw material of Class A and B. Table 4.25 summarise the reorder point of Class A and B.

Table 4.25: Reorder point of Class A and B

Raw Material In Class A	Reorder point High Season	Reorder point Low Season	Raw Material In Class B	Reorder point High Season	Reorder point Low Season
RS-022	10 pails	4 pails	IP-222	3 pails and 6 bags	1 pail and 2 bags
HP-18	10 bags	4 bags	T-47/A	1 pail	1 pail
M-50	3 bags	2 bags	M-56	2 bags	2 bags
IP-820	11 bags	6 bags	IP-555	2 pails and 19 bags	1 pail and 2 bags
IP-333	7 pails and 11 bags	2 pails and 12 bags	M-10	1 bag	1 bag
			IP-28	19 bags	7 bags
			M-32	2 bags	2 bags

The maximum stock, economic order quantity, reorder point, and safety stock of Class A and B are shown in Table 4.26. Maximum stock shows the highest volume of stock that an organisation should be. Economic order quantity shows the quantity to order when the stock get down to reorder level, and safety stock shows the quantity that an organisation should be kept for protect the stockout.

Table 4.26: The variable results for inventory control

RM	Maximum stock		EOQ		Reorder point		Safety stock	
Class A	High Season	Low Season	High Season	Low Season	High Season	Low Season	High Season	Low Seasor
RS-022	35 pails	27 pails	29 pails	26 pails	10 pails	4 pails	6 pails	1 pail
HP-18	42 bags	34 bags	36 bags	33 bags	10 bags	4 bags	6 bags	1 bag
M-50	13 bags	11 bags	11 bags	10 bags	3 bags	2 bags	2 bags	1 bag
IP-820	63 bags	54 bags	56 bags	52 bags	11 bags	6 bags	7 bags	2 bags
IP-333	58 pails and 16 bags	47 pails and 18 bags	54 pails and 8 bags	47 pails and 15 bags	7 pails and 11 bags	2 pails and 12 bags	4 pails and 8 bags	3 bags

Raw Material In	Maximum stock		EOQ		Reorder point		Safety stock	
Class B	High Season	Low Season	High Season	Low Season	High Season	Low Season	High Season	Low Seasoı
IP-222	28 pails and 1 bag	24 pails and 1 bag	26 pails and 2 bags	23 pails	3 pails and 6 bags	1 pail and 2 bags	1 pail and 19 bags	1 bag
T-47/A	5 pails	5 pails	4 pails	4 pails	1 pail	1 pail	1 pail	1 pail
M-56	7 bags	7 bags	6 bags	6 bags	2 bags	2 bags	1 bag	1 bag
IP-555	29 pails and 3 bags	24 pails and 4 bags	27 pails and 9 bags	24 pails and 1 bags	2 pails and 19 bags	1 pail and 2 bags	1 pail and 14 bags	3 bags
M-10	7 bags	6 bags	6 bags	5 bags	1 bag	1 bag	1 bag	1 bag
IP-28	199 bags	165 bags	188bags	164 bags	19 bags	7 bags	11 bags	1 bag
M-32	13 bags	12 bags	12 bags	11 bags	2 bags	2 bags	1 bag	1 bag

4.3.4 Fixed-Time Period Models (P model)

Fixed-time period models concern only interval time to review stock. For this model, it suitable for Class C because Class C give the lowest inventory value that is 9.06 percent but it has a lot of items. Therefore time period review is appropriate in this class.

Condition of an industry for Class C:

An organisation wants to combine orders for several items into a single order in every quarter (T = 3 months) due to this group is less important.

4.3.4.1 Safety stock

The equation of safety stock in this model is:

$$SS = z\sigma_{T+L} = z\sqrt{(T + LT)\sigma_d^2}$$

Assumption:

1. Demand usage is normal distribution
2. Leadtime is constant that equals to 2 days or 0.066 month
3. A manager defines the risk of stockout less than 2% (z = 2.06)

Raw material WDOR-100:

The calculation of standard deviation of demand is shown in Table 4.27

Table 4.27: Calculation of standard deviation of demand (σ_p) of WDOR-100

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- ā)^2$
Q1-04	92.67	83.87	8.80	77.46
Q2-04	122.20	83.87	38.33	1469.20
Q3-04	66.72	83.87	-17.16	294.32
Q4-04	53.90	83.87	-29.98	898.53
Total	335.49			2739.50
Average (ā)	83.87			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{2739.5}{4}} = 26.17$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)26.17^2} \approx 95$$

An organisation should keep safety stock of raw material WDOR-100 95 kg or 4 pails.

Raw material T-27:

The calculation of standard deviation of demand is shown in Table 4.28

Table 4.28: Calculation of standard deviation of demand (σ_p) of T-27

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- ā)^2$
Q1-04	551.39	526.81	24.59	604.48
Q2-04	624.18	526.81	97.37	9481.71
Q3-04	463.55	526.81	-63.26	4002.19
Q4-04	468.11	526.81	-58.70	3445.39
Total	2107.23			17533.79
Average (ā)	526.81			

The standard deviation of demand is:

$$\sigma_t = \sqrt{\frac{17533.79}{4}} = 66.21$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066 + 3)66.21^2} \approx 239$$

An organisation should keep safety stock of raw material T-27 229 kg or two pails.

Raw material M-85:

The calculation of standard deviation of demand is shown in Table 4.29

Table 4.29: Calculation of standard deviation of demand (σ_p) of M-85

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	121.78	114.77	7.01	49.15
Q2-04	136.64	114.77	21.87	478.42
Q3-04	99.57	114.77	-15.20	230.99
Q4-04	101.09	114.77	-13.68	187.28
Total	459.08			945.84
Average (ā)	114.77			

The standard deviation of demand is:

$$\sigma_t = \sqrt{\frac{945.84}{4}} = 15.38$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066 + 3)15.38^2} \approx 56$$

An organisation should keep safety stock of raw material M-85 56 kg or 3 pails.

Raw material M-92:

The calculation of standard deviation of demand is shown in Table 4.30

Table 4.30: Calculation of standard deviation of demand (σ_p) of M-92

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	161.84	155.56	6.28	39.46
Q2-04	183.85	155.56	28.29	800.47
Q3-04	138.36	155.56	-17.19	295.66
Q4-04	138.18	155.56	-17.38	302.05
Total	622.23			1437.65
Average (ā)	155.56			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{1437.65}{4}} = 18.96$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)18.96^2} \approx 69$$

An organisation should keep safety stock of raw material M-92 69 kg or three pails.

Raw material M-75:

The calculation of standard deviation of demand is shown in Table 4.31

Table 4.31: Calculation of standard deviation of demand (σ_p) of M-75

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	248.60	234.66	13.94	194.22
Q2-04	279.32	234.66	44.66	1994.46
Q3-04	203.43	234.66	-31.23	975.34
Q4-04	207.30	234.66	-27.37	748.85
Total	938.66			3912.87
Average (ā)	234.66			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{3912.87}{4}} = 31.28$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)31.28^2} \approx 113$$

An organisation should keep safety stock of raw material M-75 113 kg or one pail.

Raw material WDYE-32:

The calculation of standard deviation of demand is shown in Table 4.32

Table 4.32: Calculation of standard deviation of demand (σ_p) of WDYE-32

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	39.44	32.86	6.58	43.31
Q2-04	47.81	32.86	14.95	223.43
Q3-04	20.93	32.86	-11.92	142.20
Q4-04	23.25	32.86	-9.60	92.24
Total	131.43			501.17
Average (ā)	32.86			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{501.19}{4}} = 11.19$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)11.19^2} \approx 41$$

An organisation should keep safety stock of raw material WDYE-32 41 kg or two pails.

Raw material LP-100:

The calculation of standard deviation of demand is shown in Table 4.33

Table 4.33: Calculation of standard deviation of demand (σ_p) of LP-100

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	233.63	221.17	12.46	155.33
Q2-04	262.70	221.17	41.53	1725.11
Q3-04	191.85	221.17	-29.31	859.22
Q4-04	196.48	221.17	-24.69	609.36
Total	884.67			3349.03
Average (ā)	221.17			

The standard deviation of demand is:

$$\sigma_{\iota} = \sqrt{\frac{3349.03}{4}} = 28.94$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)28.94^2} \approx 105$$

An organisation should keep safety stock of raw material LP-100 105 kg or one pail.

Raw material M-46:

The calculation of standard deviation of demand is shown in Table 4.34

Table 4.34: Calculation of standard deviation of demand (σ_p) of M-46

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	260.34	252.04	8.30	68.97
Q2-04	296.84	252.04	44.81	2007.55
Q3-04	223.19	252.04	-28.85	832.43
Q4-04	227.78	252.04	-24.26	588.49
Total	1008.15			3497.44
Average (ā)	252.04			

The standard deviation of demand is:

$$\sigma_{\iota} = \sqrt{\frac{3497.44}{4}} = 29.57$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)29.57^2} \approx 107$$

An organisation should keep safety stock of raw material M-46 107 kg or 5 bags.

Raw material M-95:

The calculation of standard deviation of demand is shown in Table 4.35

Table 4.35: Calculation of standard deviation of demand (σ_p) of M-95

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	50.72	49.95	0.77	0.59
Q2-04	58.99	49.95	9.04	81.75
Q3-04	46.75	49.95	-3.20	10.25
Q4-04	43.34	49.95	-6.61	43.69
Total	199.81			136.28
Average (ā)	49.95			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{136.28}{4}} = 5.84$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)5.84^2} \approx 21$$

An organisation should keep safety stock of raw material M-95 21 kg so it should keep in one pail due to one pail equal to 190.56 kg and for protect shelf life.

Raw material M-87:

The calculation of standard deviation of demand is shown in Table 4.36

Table 4.36: Calculation of standard deviation of demand (σ_p) of M-87

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	169.23	161.34	7.89	62.32
Q2-04	190.91	161.34	29.57	874.53
Q3-04	142.91	161.34	-18.43	339.48
Q4-04	142.29	161.34	-19.04	362.59
Total	645.34			1638.92
Average (ā)	161.34			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{1638.92}{4}} = 20.24$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)20.24^2} \approx 73$$

An organisation should keep safety stock of raw material M-87 73 kg or three pails.

Raw material WDYE-75:

The calculation of standard deviation of demand is shown in Table 4.37

Table 4.37: Calculation of standard deviation of demand (σ_p) of WDYE-75

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	17.96	16.40	1.56	2.44
Q2-04	24.87	16.40	8.47	71.71
Q3-04	12.72	16.40	-3.68	13.56
Q4-04	10.05	16.40	-6.35	40.31
Total	65.61			128.02
Average (ā)	16.40			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{128.02}{4}} = 5.66$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)5.66^2} \approx 21$$

An organisation should keep safety stock of raw material WDYE-75 21 kg or one pail.

Raw material WDCE-15:

The calculation of standard deviation of demand is shown in Table 4.38

Table 4.38: Calculation of standard deviation of demand (σ_p) of WDCE-15

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	8.88	7.51	1.37	1.87
Q2-04	11.39	7.51	3.87	15.00
Q3-04	5.09	7.51	-2.43	5.88
Q4-04	4.70	7.51	-2.82	7.93
Total	30.06			30.68
Average (ā)	7.51			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{30.68}{4}} = 2.77$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)2.77^2} \approx 10$$

An organisation should keep safety stock of raw material WDCE-15 10 kg or one pail.

Raw material M-48:

The calculation of standard deviation of demand is shown in Table 4.39

Table 4.39: Calculation of standard deviation of demand (σ_p) of M-48

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	321.67	304.78	16.89	285.12
Q2-04	363.06	304.78	58.28	3396.44
Q3-04	268.04	304.78	-36.74	1349.66
Q4-04	266.35	304.78	-38.43	1476.62
Total	1219.12			6507.83
Average (ā)	304.78			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{6507.83}{4}} = 40.34$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)40.34^2} \approx 146$$

An organisation should keep safety stock of raw material M-48 146 kg or 7 pails.

Raw material WDYE-180:

The calculation of standard deviation of demand is shown in Table 4.40

Table 4.40: Calculation of standard deviation of demand (σ_p) of WDYE-180

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	31.23	27.45	3.78	14.29
Q2-04	44.03	27.45	16.58	274.83
Q3-04	20.08	27.45	-7.37	54.29
Q4-04	14.46	27.45	-12.99	168.76
Total	109.80			512.17
Average (ā)	27.45			

The standard deviation of demand is:

$$\sigma_d = \sqrt{\frac{512.17}{4}} = 11.32$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)11.32^2} \approx 41$$

An organisation should keep safety stock of raw material WDYE-180 41 kg or 2 pails.

Raw material WDBE-690:

The calculation of standard deviation of demand is shown in Table 4.41

Table 4.41: Calculation of standard deviation of demand (σ_p) of WDBE-690

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	(a- ā)^2
Q1-04	6.96	6.37	0.59	0.35
Q2-04	9.23	6.37	2.87	8.22
Q3-04	4.85	6.37	-1.52	2.30
Q4-04	4.42	6.37	-1.94	3.78
Total	25.47			14.65
Average (ā)	6.37			

The standard deviation of demand is:

$$\sigma_t = \sqrt{\frac{14.65}{4}} = 1.91$$

Therefore, safety stock is:

$$ss = 2.06\sqrt{(0.066+3)1.91^2} \approx 7$$

An organisation should keep safety stock of raw material WDBE-690 7 kg or one pail.

Raw material WDBK-50:

The calculation of standard deviation of demand is shown in Table 4.42

Table 4.42: Calculation of standard deviation of demand (σ_p) of WDBK-50

Quarter	Forecasting demand usage (Kg)	ā	(a - ā)	$(a- ā)^2$
Q1-04	19.13	16.92	2.21	4.87
Q2-04	24.86	16.92	7.94	63.06
Q3-04	13.05	16.92	-3.87	15.00
Q4-04	10.65	16.92	-6.27	39.36
Total	67.68			122.29
Average (ā)	16.92			

The standard deviation of demand is:

$$\sigma_{d} = \sqrt{\frac{122.29}{4}} = 5.53$$

Therefore, safety stock is:

$$SS = 2.06\sqrt{(0.066+3)5.53^{2}} \approx 20$$

An organisation should keep safety stock of raw material WDBK-50 20 kg or one pail.

4.3.4.2 Target stock level

After know the safety stock, an organisation has to know the target stock to order in each time. Table 4.43 shows the maximum stock of raw materials in Class C.

$$Target\ stock\ level = \bar{d}(T + LT) + SS$$

where $\bar{d}$ = average demand in monthly

Table 4.43: Target stock level of raw material in Class C

Raw Material	$\bar{d}$	Safety stock	Target stock level	Target stock level
T = 3 months and LT = 0.066 month		(Kg)	(Kg)	(Pail or Bag)
WDOR-100	27.96	100	185.72	8 pails
T-27	175.60	380	918.40	5 pails
M-85	38.26	75	192.30	8 pails
M-92	51.85	90	248.97	9 pails
M-75	78.22	180	419.82	3 pails
WDYE-32	10.95	50	83.58	4 pails
LP-100	73.72	200	426.03	3 pails
M-46	84.01	125	382.58	16 bags
M-95	16.65	190.56	241.61	2 pails
M-87	53.78	75	239.89	10 bags
WDYE-75	5.47	25	41.76	2 pails
WDCE-15	2.50	25	32.68	2 pails
M-48	101.59	154	465.48	22 pails
WDYE-180	9.15	50	78.05	4 pails
WDBE-690	2.12	25	31.51	2 pails
WDBK-50	5.64	25	42.29	2 pails

4.3.4.3 Order quantity

The quantity to order (q) in this model is the sum of average demand over the vulnerable period with safety stock and minus inventory on hand. Table 4.44 shows the approximately inventory on hand of Class C in December 2003.

Table 4.44: Inventory on hand in December 2003

Item	Raw Material	Inventory On Hand (kg)	Item	Raw Material	Inventory On Hand (kg)
1	WDOR-100	75	9	M-95	55
2	T-27	600	10	M-87	60
3	M-85	40	11	WDYE-75	15
4	M-92	140	12	WDCE-15	40
5	M-75	370	13	M-48	210
6	WDYE-32	95	14	WDYE-180	80
7	LP-100	230	15	WDBE-690	65
8	M-46	245	16	WDBK-50	25

For raw material WDOR-100,

$$q = 27.96\ (3 + 0.066\ ) + 100 - 75 = 111$$

An organisation has to order 111 kg or approximately 5 pails in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.45

Table 4.45: The quantity order in each period of WDOR-100

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				75
1 (04)	93	125 (5 pails)	200	107
2 (04)	122	75 (3 pails)	182	60
3 (04)	67	125 (5 pails)	185	118
4 (04)	54	75 (3 pails)	193	139

(Note: 1 pail = 25 kg, Target stock level = 8 pails or 200 kg, SS = 100 kg)

From this table, at second quarter, demand is highest so safety stock protected the stockout. In quarter three, order quantity from calculation is 118 (27.96(3+0.066)+100-60) kg but, in reality, an organisation can order in pail so it should be ordered 5 pails or 6 pails. If an organisation order 6 pails or 150 kg, it over target stock level so it should be ordered 5 pails.

For raw material T-27,

$$q = 175.6\,(3 + 0.066) + 380 - 600 = 318$$

An organisation has to order 318 kg or 2 pails in the end of March 04 but target stock level is 950 kg so order 1 pail. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.46

Table 4.46: The quantity order in each period of T-27

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				600
1 (04)	551	190 (1 pail)	790	239
2 (04)	624	570 (3 pails)	809	185
3 (04)	464	760 (4 pails)	945	481
4 (04)	468	380 (2 pails)	861	393

(**Note:** 1 pail = 190 kg, Target stock level = 5 pails or 950 kg, SS limit at 380 kg)

For raw material M-85,

$$q = 38.26\,(3 + 0.066) + 75 - 40 = 152$$

An organisation has to order 152 kg or approximately 6 pails in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.47

Table 4.47: The quantity order in each period of M-85

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				40
1 (04)	122	150 (6 pails)	190	68
2 (04)	137	125 (5 pails)	193	56
3 (04)	100	125 (5 pails)	181	81
4 (04)	101	100 (4 pails)	181	80

(**Note:** 1 pail = 25 kg, Target stock level = 8 pail or 200 kg, SS limit at 75 kg)

From this table, stock on hand should not keep over than target stock level or 200 kg.

For raw material M-92,

$$q = 51.85\,(3 + 0.066) + 90 - 140 = 108.97$$

An organisation has to order 109 kg or approximately 3 pails in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.48

Table 4.48: The quantity order in each period of M-92

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				140
1 (04)	162	90 (3 pails)	230	68
2 (04)	184	180 (6 pails)	248	64
3 (04)	138	180 (6 pails)	244	106
4 (04)	138	150 (5 pails)	256	118

(**Note:** 1 pail = 30 kg, Target stock level = 9 pails or 270 kg, SS limit at 90 kg)

For raw material M-75,

$$q = 78.22\,(3 + 0.066) + 180 - 370 = 49.82$$

An organisation has to order 49.82 kg or no order in the end of March 04 because if order, it over target stock level. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.49

Table 4.49: The quantity order in each period of M-75

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				370
1 (04)	249	0	370	121
2 (04)	279	360 (2 pails)	481	202
3 (04)	203	180 (1 pail)	382	179
4 (04)	207	360 (2 pails)	539	332

(**Note:** 1 pail = 180 kg, Target stock level = 3 pails or 540 kg, SS limit at 180 kg)

For raw material WDYE-32,

$$q = 10.95(3 + 0.066) + 50 - 95 = -11.4$$

An organisation has to order −11.4 kg or no order in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.50

Table 4.50: The quantity order in each period of WDYE-32

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				95
1 (04)	39	0	95	56
2 (04)	48	25 (1 pail)	81	33
3 (04)	21	50 (2 pails)	83	62
4 (04)	23	25 (1 pail)	87	64

(Note: 1 pail = 25 kg, Target stock level = 4 pails or 100 kg, SS limit at 50 kg)

For raw material LP-100,

$$q = 73.72(3 + 0.066) + 200 - 230 = 196$$

An organisation has to order 196 kg or 1 pail in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.51

Table 4.51: The quantity order in each period of LP-100

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				230
1 (04)	234	200 (1 pail)	430	196
2 (04)	263	400 (2 pails)	596	333
3 (04)	192	200 (1 pail)	533	341
4 (04)	196	200 (1 pail)	541	345

(Note: 1 pail = 200 kg, Target stock level = 3 pails or 600 kg, SS limit at 200 kg)

For raw material M-46,

$$q = 84.01(3 + 0.066) + 125 - 245 = 138$$

An organisation has to order 138 kg or approximately 6 bags in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.52

Table 4.52: The quantity order in each period of M-46

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				245
1 (04)	260	150 (6 bags)	395	135
2 (04)	297	250 (10 bags)	385	88
3 (04)	223	300 (12 bags)	388	155
4 (04)	228	225 (9 bags)	380	152

(**Note:** 1 bag = 25 kg, Target stock level = 16 bags or 400 kg, SS limit at 125kg)

For raw material M-95,

$$q = 16.65(3 + 0.066) + 190.56 - 55 = 186.6$$

An organisation has to order 186.6 kg or 1 pail in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.53

Table 4.53: The quantity order in each period of M-95

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				55
1 (04)	51	190.56 (1 pail)	245.56	194.56
2 (04)	59	0	194.56	127.56
3 (04)	47	190.56 (1 pail)	318.12	271.12
4 (04)	43	0	271.12	228.12

(**Note:** 1 pail = 190.56 kg, Target stock level = 2 pail or 381.12 kg, SS limit at 190.56 kg)

For raw material M-87,

$$q = 53.78(3 + 0.066) + 75 - 60 = 180$$

An organisation has to order 180 kg or 7 bags in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.54

Table 4.54: The quantity order in each period of M-87

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				60
1 (04)	169	175 (7 bags)	235	66
2 (04)	191	175 (7 bags)	241	50
3 (04)	143	200 (8 bags)	250	107
4 (04)	142	125 (5 bags)	232	142

(**Note:** 1 bag = 25 kg, Target stock level = 10 bags or 250 kg, SS limit at 75 kg)

For raw material WDYE-75,

$$q = 5.47(3+0.066)+25-15 = 27$$

An organisation has to order 27 kg or 1 pail in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.55

Table 4.55: The quantity order in each period of WDYE-75

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				15
1 (04)	18	25 (1 pail)	40	22
2 (04)	25	25 (1 pail)	47	22
3 (04)	13	25 (1 pail)	47	34
4 (04)	10	0	34	24

(**Note:** 1 pail = 25 kg, Target stock level = 2 pails or 50 kg, SS limit at 25 kg)

For raw material WDCE-15,

$$q = 2.5(3+0.066)+25-40 = -7.34$$

An organisation doesn't to order in the end of March 04 because stock on hand is enough for next order. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.56

Table 4.56: The quantity order in each period of WDCE-15

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				40
1 (04)	9	0	40	31
2 (04)	11	0	31	20
3 (04)	5	25 (1 pail)	45	40
4 (04)	5	0	40	35

(**Note:** 1 pail = 25 kg, Target stock level = 2 pails or 50 kg, SS limit at 25 kg)

For raw material M-48,

$$q = 101.59(3+0.066)+154-210 = 255.48$$

An organisation has to order 255.48 kg or 12 pails in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.57

Table 4.57: The quantity order in each period of M-48

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				210
1 (04)	322	264 (12 pails)	474	152
2 (04)	363	330 (15 pails)	482	119
3 (04)	268	352 (16 pails)	471	203
4 (04)	266	264 (12 pails)	467	201

(**Note:** 1 pail = 22 kg, Target stock level = 22 pails or 484 kg, SS limit at 154 kg)

For raw material WDYE-180,

$$q = 9.15(3+0.066)+50-80 = -1.95$$

An organisation doesn't to order in the end of March 04 because stock on hand is enough for next order. Observe that stock on hand is 80 kg but target stock level is 75 kg so it's bigger than 75 kg only that quarter because, in quarter Q4-03, it is the quarter before improve inventory management. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.58

Table 4.58: The quantity order in each period of WDYE-180

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				80
1 (04)	31	0	80	49
2 (04)	44	25 (1 pail)	74	30
3 (04)	20	25 (1 pail)	55	35
4 (04)	14	25 (1 pail)	60	46

(**Note:** 1 pail = 25 kg, Target stock level = 3 pails or 75 kg, SS limit at 25 kg)

For raw material WDBE-690,

$$q = 2.12(3+0.066)+25-65 = -33.5$$

An organisation doesn't to order in the end of March 04 because stock on hand is enough for next order. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.59

Table 4.59: The quantity order in each period of WDBE-690

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				65
1 (04)	7	0	65	58
2 (04)	9	0	58	49
3 (04)	5	0	49	44
4 (04)	4	0	44	40

(**Note:** 1 pail = 25 kg, Target stock level = 2 pails or 50 kg, SS limit at 25 kg)

For raw material WDBK-50,

$$q = 5.64(3+0.066)+25-25 = 17.29$$

An organisation has to order 17.29 kg in the end of March 04. If the forecasting demand is truth, the quantity order in each time is shown in Table 4.60

Table 4.60: The quantity order in each period of WDBK-50

Quarter	Forecast (Kg)	Order Quantity (Kg)	Stock on hand (Before use)	Stock on hand (After used)
4 (03)				25
1 (04)	19	25 (1 pail)	50	31
2 (04)	25	0	31	6
3 (04)	13	25 (1 pail)	31	18
4 (04)	11	25 (1 pail)	43	32

(**Note:** 1 pail = 25 kg, Target stock level = 2 pails or 50 kg, SS limit at 25 kg)

All of these are the order quantity in each quarter of each raw material. A manager doesn't care about the inventory level in Class C. It means it will check stock level in every three months. In the other hand, for fixed-order quantity, it is the important raw materials so the workers should always check the inventory level and keep record and order in fixed quantity. When the inventory level gets down to the reorder point, it orders in the same quantity.

Moreover safety stock has the important role to protect raw materials shortage, especially, in fixed order period safety stock always use because of demand uncertainty but time to order is fixed.

4.3.5 Order quantity with limited area

One thing an organisation should be concerned when orders raw materials that are the area to storage. An organisation should know the space area how much space can be storage. In the moment, a factory has some problems about area to storage raw materials. The reasons may come from an organisation doesn't have exactly inventory policy in term of order quantity so they used own experience to judgment how much to order.

But, now order quantities of all raw materials are known so the next step present how to know these order quantities will support to the limited storage space. The equation is:

$$f_1Q_1 + f_2Q_2 + \ldots + f_kQ_k + \ldots + f_nQ_n < F$$

where F = the storage area size for raw material

f_k = the size of each raw material in a unit

n = the number of raw material types

Q = order quantity

From this equation, if the answer is true, an organisation can use their order quantities to order. But if the answer is wrong, an organisation has to adjust to order quantities.

In this factory, the storage area space is divided into 2 stages: first stage has W22.8ft * L180.5ft. Second stage is W649.8ft * L9.5ft and W24.7ft * L57ft. So total storage space is approximately 4800 ft^2

For raw materials size is shown in Table 4.61.

(**Remark:** **1**. the shape of a cylinder, calculate in square area because when it place on the floor and place another beside, the unnecessary area occurs around the pail.

2. Order quantities—for fixed-order quantities is EOQ in high demand season (See in Table 4.10), and for fixed-order period is maximum order quantity (See in Table 4.43)).

Table 4.61: The area of each raw material

Item	Raw Material	Raw Material Area (ft^2)	Item	Raw Material	Raw Material Area (ft^2)
1	RS-022	2.25	15	M-85	1
2	HP-18	11.11	16	M-92	1
3	M-50	11.11	17	M-75	4
4	IP-820	11.11	18	WDYE-32	2.25
5	IP-333	11.11 for pail and 1 for bag	19	LP-100	4
6	IP-222	11.11 for pail and 1 for bag	20	M-46	4.5
7	T-47/A	4	21	M-95	4
8	M-56	3	22	M-87	3
9	IP-555	11.11 for pail and 1 for bag	23	WDYE-75	2.25
10	M-10	1	24	WDCE-15	2.25
11	IP-28	1	25	M-48	1
12	M-32	1	26	WDYE-180	2.25
13	WDOR-100	2.25	27	WDBE-690	2.25
14	T-27	4	28	WDBK-50	2.25

Therefore, the equation is: (started from Class A to Class C)

2.25(29)+11.11(36)+11.11(11)+11.11(56)+((11.11*54)+(1*8))+((11.11*26)+(1*2))+ 4(4)+3(6)+((11.11*27)+(1*9))+1(6)+1(188)+1(12)+2.25(8)+4(5)+1(8)+1(9)+4(3)+2. 25(4)+4(3)+4.5(16)+4(2)+3(10)+2.25(2)+2.25(2)+1(22)+2.25(3)+2.25(2)+2.25(2) < 4800 ft^2

$$2902 \text{ ft}^2 < 4800 \text{ ft}^2$$

The answer is truth so an organisation accepted all these order quantities to order raw materials without any problems with storage space because of EOQs are the optimal quantity to order so it can save the area for expand business in the future.

In addition, if the total area of raw materials is bigger than total storage space, an organisation has to two options. First an organisation has to redesign the layout of storage space but in this thesis doesn't focus to redesign layout of storage space so an organisation has to continue in second option that is reducing volume of economic order quantities by using Lagrange Multiplier Technique. It has Lagrange multiplier (λ) to reduce in order quantities. For example, an organisation has 3 raw materials that consisting of these area: 2 ft^2, 3 ft^2, and 4 ft^2 respectively. The economic order quantities are 5, 6, and 7 units respectively. The storage is limited in 50 ft^2.

Therefore: $5(2) + 6(3) + 7(4) \leq 50 \text{ ft}^2$

$$56 \text{ ft}^2 \leq 50 \text{ ft}^2$$

Lagrange Multiplier is:

$$f_1\sqrt{\frac{2c_{o1}D_1}{c_{h1}+2\lambda f_1}}+f_2\sqrt{\frac{2c_{o2}D_2}{c_{h2}+2\lambda f_2}}+f_3\sqrt{\frac{2c_{o3}D_3}{c_{h3}+2\lambda f_3}}+\dots+f_k\sqrt{\frac{2c_{ok}D_k}{c_{hk}+2\lambda f_k}}=F$$

where f_k = Raw material area

λ = Lagrange multiplier

F = Total area of storage space

Substitute, demands these three raw materials = 100 units, C_h=10, and C_o=20

$$2\sqrt{\frac{2*20*100}{10+2\lambda(2)}}+3\sqrt{\frac{2\cdot 20*100}{10+2\lambda(3)}}+4\sqrt{\frac{2\cdot 20*100}{10+2\lambda(4)}}=50$$

Thus, from this equation, λ is 19.47

Then substitute λ for solve new economic order quantity.

$$Q_k=\sqrt{\frac{2C_{ok}D_k}{C_{hk}+2(19.47)f_k}}$$

Therefore

$$Q_1=\sqrt{\frac{2*20*100}{10+2(19.47)2}}=6.75$$

$$Q_2=\sqrt{\frac{2*20*100}{10+2(19.47)3}}=5.62$$

$$Q_3=\sqrt{\frac{2*20*100}{10+2(19.47)4}}=4.91$$

Check the total area of raw materials and total storage space again

$$6.75(2)+5.62(3)+4.91(4)\le 50\ ft^2$$

$$50\ ft^2\le 50\ ft^2$$

From Lagrange multiplier model, it adjusts the order quantities for fit with the storage space of raw material. New order quantities are Q_1=6.75, Q_2=5.62, and Q_3=4.91. So an organisation can use these new quantities replace to old order quantities.