Use and Application of Selective Inventory Control Techniques of Spares for a Chemical Processing Plant

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Abstract:-**This paper presents the implementation of an improved inventory management and control system of a chemical processing industry. Inventory management system involves the procurement, stocking, and issue of materials to the maintenance department as and when required. Inventory management is the main area in which many process industries are suffering. The work is concentrated on the inventory management problems of a chlor-alkali industry. The aim of this work is to design inventory models for such a system in a process industry. The existing system of inventory control of spares reveals that past data cannot be taken as the major decision criteria. The important decision making criterion related to spares is criticality, lead time and consumption value which need to be accounted for effective control of inventory management in the organization. Data are collected from various sources like log books, ledgers, annual financial statements and published articles of the company. Interview method is used to collect primary data regarding the existing inventory management system. ABC Analysis, selective ABC and VED analysis, lead time and service level are incorporated in order to obtain 3D models and suggestions were given to improve the inventory management of spares. The key performance indicators were also established to give benchmark operations. Simulation technique is used to obtain the optimum re-order quantity and minimum total cost, which are also analyzed in this paper.**

Keywords: Selective inventory control, ABC, VED, MUSIC-3D Simulation, Re-order level and Quantity

I. INTRODUCTION

The present study is conducted in a chemical industry named as Travancore Cochin Chemicals Limited, located at Ernakulum district. This company has a history of more than 60 years of service in chemical processing. The chemical industry plays a vital role in the production of many manufacturing goods. It produces chemical products that benefits people directly. The Indian chlor-alkali industry is driven by the demand for caustic soda and chlorine is considered as a by-product. Today, chemical processing industries in India are facing certain challenges that will be tackled for the survival of these organizations in the era of globalization. Inventory is often a company's largest current asset and the single largest contributor of working capital requirements. If inventory is properly managed, working capital requirements are reduced and cash flow is increased, enhancing the organization's chances to prosper and grow. In this analysis a systematic approach has been adopted to identify the inventory management problems of the chemical company and suggestions are recommended to improve the inventory management system. ABC, VED analysis and their combination along with lead time and reorder level and re order quantity are used to analyze the inventory problems. The major problem related to inventory problem is uncertainty in demand and lead time, which are considered in the present study.

II. OBJECTIVES OF THE WORK

(1) To study the existing inventory control of spares

(2) To identify appropriate selective inventory control tool

(3) To study and model selective inventory control of spares

(4) To analyze the three-dimensional approach for multi--selective inventory control (MUSIC-3D)

(5) To suggest optimum re order level and re order quantity using simulation

III. LITERATURE SURVEY

The one common mistake in inventory control is identified by Institute of Financial Management and Research [1] is to treat inventories in the same manner as costs and treat low inventories as desirable. The purpose of inventories is to allow for economic purchases and production quantities and to provide for uncertainties in the production process, market demand and sources of supply. **Goal [2]** said that inventories can also help to isolate or minimize the interdependence of each part of the organization, so that it may work more efficiently as becomes evident when many parts and subassemblies are purchased or manufactured, stored and used according to the needs. **Gopalakrishnan (3**) found in all cases company's working capital would be tied up. The finance manager is way of servicing the idle working capital at 30% per annum on the contrary if the item is kept in the store, there will be stock out if the demand arrives. **Viale (4)** said that objectives of inventory are minimizing investments while still providing a high level of customer service, maximizing profit, and providing for effectiveness in procurement and manufacturing. **Chakraborthy (5)** opinioned that inventories represent the major part of working capital management and an inventory has both physical and functional aspects [6]. VED analysis is most applicable to spare parts [7]. The generally accepted 80:20 rule illustrates that approximately 80 percent of any storeroom's volume is associated with only 20% of the items in inventory. It is important to pay extra attention to that critical 20% items [8]. A survey carried out in India showed that on an average 64% of the total cost of manufacturing is that of materials. This percentage however differs from industry to industry [9]. It is advisable to define maintenance or spares supply service policies specifying the levels of availability to be achieved first and then workout inventory policies for individual items to meet the service requirements with given procurement infrastructure [10]. Forecasting the required number of spare parts, based on technical characteristics and operating environmental conditions of a system, is one of the best ways to optimize unplanned stoppages [11]. The study reveals the need of inventory control and inventory reduction in the industries. A 2-D matrix of the ABC-VED analysis has been constructed for inventory modelling to achieve high efficiency [12]. **Onwubolu** (2007) said that there are various inventory management tools like EFFN, AHP, COCOMOII, C#.NET and Visual Basic programs that enables the user to find the best way to manage inventory [13]. Based on the above literature an analysis lacks in to find optimum ROQ and minimum total cost at uncertainty in demand and lead time. Hence it is decided to design a model for simulation to find solution for the above.

IV RESEARCH METHODOLOGY

Initially the discussions are made with the Manager (stores and inventory control) and stores officers to clarify the doubts and study the existing system of keeping inventory. Data are collected from the above said sources, ERP data and using questionnaire survey. Hand outs, registers are also made use of to collect secondary data. Reliability test of the questionnaire is analyzed, since a sample size of 62 from a population of 74, is selected and a questionnaire was distributed to 62 experts, out of which 58 responded. Using 55 valid responses, an analysis is conducted in SPSS 20 for testing the reliability. It is found that at 95% confidence level the Cranbach's Alpha is 0.82. The data collected are found to be good since the respondents responded to the questionnaire differently. ABC and VED analysis are done to categorize the spare parts on the basis of usage value and criticality. There are twenty three critical factors identified for equipment classification, Out of which eight factors which are most important are selected. The factors are (1) % utilization of machine (2) Number of alternative machine (3) Effect on other machines due to break down (4) Age of machine (5) Ease of repair (6) Quality of work done on the equipment (7) Ease in procurement and (8) Maintenance history. Weight age are assigned to each factor such that total score is 100%. The most important factors are assigned higher weight age as compared to less important factors.

Vital - criticality score over 80%
Very important - criticality score between 60%& 80%
Important - criticality score between 40%& 60%
Least important - criticality score below 40%

The analyses are then combined using a control matrix which will provide better control of inventory. The key performance indicators were also established to give benchmark to operations. Uncertainty in demand and lead time are also taken in to account and solutions are given with the help of simulation model. A computer programme is coded and a graphic user interface (GUI) is developed in MATLAB 2008 to calculate optimum ROQ with minimum total cost for most critical items.

A. ABC Analysis

ABC classification is the most popular and it classifies inventory into three distinct classes. A- Class items are those which are found to be hardly 5% to 15% of total items with their consumption value being 70% to 75% of the total money spend on materials. B- Class items are generally 10% to 20% of the total items and their consumption amounts to 10% to 20% of the money spend on the materials. C- Class items are large number of items which are cheap and inexpensive and hence insignificant. These are vary from 5% to 10% of the total money spends on materials.

B. Control Matrix

ABC and VED analysis are combined together for better control of inventory. The suitable treatments should be given for AV, AE, AD, BV, BE, BD, CV, CE, CD combinations as shown in Table 4.1.

Table 4.1 ABC - VED Matrix

	V	E	D
A	Constant control and regular follow up (AV)	Maintain at moderate level (AE)	Eliminate item or keep nil stock (AD)
B	Maintain at moderate level (BV)	Maintain at Moderate level (BE)	Low stock (BD)
C	Maintain at moderate level (CV)	Maintain at Moderate level (CE)	Low stock (CD)

C. Multi Unit Selective Inventory Control 3D (MUSIC 3D)

MUSIC 3D is a three dimensional approach, the three functions being finance, operations and materials. Based on ABC analysis, items are classified as high consumption value (HCV-80/20 Rule) and low consumption value (LCV-20/80 Rule). Based on VED analysis, we can classify items as critical and non critical. Long lead time (LLT) and short lead time (SLT) are based on SDE analysis, HCV items that are 20% with annual consumption value of 80% remaining 80% of LCV items account for an annual consumption value of 20% are shown in Table 4.2. Cost reduction techniques are not used for items in cells 3, 4, 7, 8 since the cost of cost reduction method is likely to be greater than the cost of the item itself.

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Table 4.2 MUSIC 3 D

	HCV		LCV	
Critical	LLT	SLT	LLT	SLT
	1	2	3	4
Non- critical	5	6	7	8

It may be dangerous to apply cost reduction technique for highly critical items falling in cells 1& 2. Therefore cost reduction technique can be applied only to items in cells 5&6. This method ensures maximum plant availability with minimum working capital commitment.

D. Inventory control systems

There are two inventory control systems commonly used—(i) continuous review system and (ii) periodic review system. An important parameter for installing an inventory control system is the service level, which is the percentage of orders that are received before a stock-out occurs in inventory control. When historic data exists, then the expected demand can follow the normal distribution pattern so that:

$$Z = X-\mu/\sigma \sim (0, 1)$$

where, mean =expected demand=μ, standard deviation, $\sigma \approx 10\%$ of μ , safety stock, S= $Z\sigma$, order point= X; the parameter X is a normally distributed variable, i.e. has a mean of 0 and a variance of 1 and Z has what is called a standardised normal distribution, i.e. one with a mean of 0 and a variance of 1 [18].

E. Development of key performance indicators

Key performance indicators (KPI) are high-level snapshots of a business or organisation based on specific predefined measures. KPIs typically consist of any combination of reports, spreadsheets, or charts. They may include global or regional sales figures and trends over time, personnel statistics and trends, real-time supply chain information, or anything else that is deemed critical to a company's success. The essence of developing key performance indicators (KPIs) are for TCC stores to carry on with their future work of benchmarking their operations using the KPIs. The standard formulae used are

Service level = (No: of requisitions serviced / Total number of requisitions) x 100%

Late service level

= (No: of requisitions not serviced on time / Total number of requisitions) x100%

This approach also provides a simple method of fixing ideal stock level of each item taking into account criticality, availability and consumption value as follows:

Ideal Stock Level = 1 + K * (Lead Time Consumption)

Where K is the safety factor varying from 0.5 to 3 is assigned to each of the eight groups based on its consumption value, criticality and lead time factor proposed to be used initially suggested in the MUSIC-3D Table 4.3.

To arrive at the ideal stock level, safety factor is multiplied by lead time consumption & unit 1 is added to the above. Unit 1 is added to signify no stock out even if lead time is zero for an item. The safety factor (K) shall be subjected to periodic review.

Table 4.3 K factor for MUSIC- 3D

Source: Vinay sharaf P&IC Hand book

Sl No	Category	Suggested K factor	Control action plan
1	Critical -High consumption value -Long lead time	1.8 to 2.0	1. Strict control on consumption norms 2. Expediting and follow up effort maximum 3. Multiple sources 4. Stock as low as possible 5. No stock out
2	Critical -High consumption value -Short lead time	1.5 to 1.7	1. Strict control on consumption norms 2. Expediting and follow up effort maximum 3. Multiple sources 4. Stock as low as possible 5. No stock out
3	Critical -Low consumption value -Long lead time	2.5 to 3.0	1. Large quantity to be ordered for annual or two years requirement 2. Adequate level of inventory(qty-plenty) 3. No stock out(100% service level)
4	Critical -Low consumption value -Short lead time	2.5 to 3.0	1. Order quantity may be quarter or six months being short lead time 2. Adequate level of inventory(qty-plenty) 3. No stock out(100% service level)
5	Non-Critical -High consumption value -Long lead time	0.8 to 1.0	1. All cost reduction techniques to be applied 2. Stock out possible 3. Low inventory level
6	Non-Critical -High consumption value -Short lead time	0.5 to 1	1. All cost reduction techniques to be applied 2. Stock out possible 3. Zero inventory or Low inventory 4. Service level minimum 5. Purchase on JIT basis
7	Non-Critical -Low consumption value -Long lead time	2.0	1. Moderate inventory level 2. Stock out Possible 3. Service level moderate
8	Non-Critical -Low consumption value -Short lead time	1.8	1. Moderate inventory level 2. Stock out Possible 3. Service level moderate

F. Use and application of MUSIC-3D

Music-3D is used in cost reduction techniques selectively. Its applications are in

- Effective follow up and chasing,
- Powers of delegation to all levels,
- Lower inventory levels,
- Selective information by continuously monitoring of high consumption value items,
- Development of new sources of supply for high value critical items
- Different service levels for different categories,
- Development of consumption norms for high value items.

G. Inventory policy.

The objective of this simulation is to choose an inventory policy that will provide good customer service at a reasonable cost. A model is developed relating two output measures, total inventory cost and the service level, to probabilistic inputs, such as product demand and delivery lead time from vendors, and controllable inputs, such as the order quantity and the reorder point as shown in Fig 4.1.

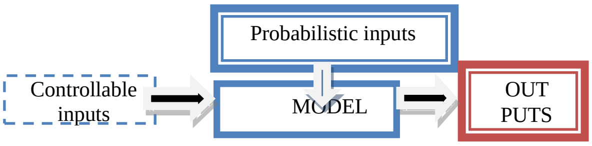

Fig.4.1 Model for simulation

For each setting of the controllable inputs, a variety of possible values would be generated for the probabilistic inputs, and the resulting cost and service levels would be computed.

H. Simulation Model

The basic idea behind simulation is to model the given system by means of some equations and they determine its time-dependent behavior. In a real life inventory management system, demand and lead time are uncertain. Hence simulation technique is used to optimize the re-order level and re-order quantity which yields the minimum total cost. The flow chart given in Fig 4.2 explains the logic of the program.

V. RESULTS AND DISCUSSION

A. Result of ABC Analysis

The result of ABC analysis is shown in Table 5.1 and in Fig. 5.1. From the graph of cumulative value vs. cumulative % of item, it is clear that around 10.54% of items are contributing 70.19% to cumulative usage value. Therefore, such items are classified as class A. Around 19.23% numbers of items are contributing to 24.84% cumulative usage value is categorized as class B. Remaining 71% number of items contributes only 4.73% to cumulative usage value is classified as class C items.

B. Result of VED Analysis

VED analysis is carried out for AGC plant. The criticality of spares is arrived by first finding the criticality of machines to which the spares belong. Based on the data collected from the plant with the help of questionnaire, all the machines in the plant are classified as vital, essential and desirable.

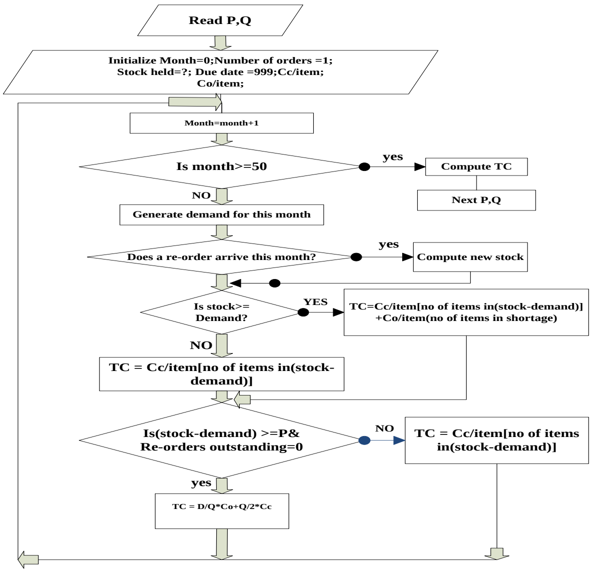

Fig. 4.2 Flow chart for the computer program

Table 5.1 Output of ABC analysis

Class	No. of Items	% of Items	Value of Usage (Rs)	% of total usage value
A (Above Rs 30000)	22	10.57	1162562	70.19
B Rs(2500-30000)	40	19.23	409741	24.84
C Below Rs 2500	146	71	77644	4.70

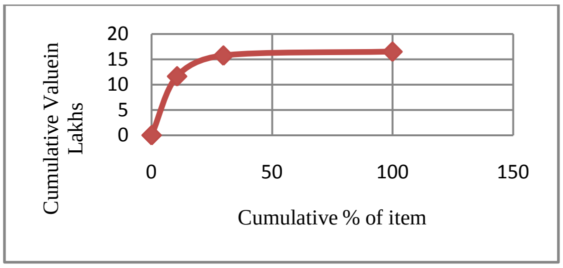

Fig 5.1 ABC Analysis

It has been found that 60 equipments are vital, 123 equipments are essential, and 52 equipments are desirable. The number of spares for vital, essential and desirable category is shown in Table 5.2. The corresponding graph is shown in Fig.5.2

C. Discussion of VED analysis

The items in vital category are the critical spares whose shortage will result in production stoppage. Therefore such items should never be out of stock and policies that will provide enough stock should be adopted for this category of spares. Essential spares should be moderately stocked since its shortage affect production after some time. Tight control can be applied for desirable spares since their stock out will not affect the production.

D. Discussion of Control Matrix

The control matrix shown in Table 5.4 is a 3x3 matrix where each cell represents a combination of any of the two classes. There is no point in controlling items in cell CD, since their consumption value and criticality are low. Items in cell AV should be given the greatest attention since their usage value and criticality are the highest. Combination of ABC and VED selective control helps to identify service levels which forms basis for inventory policies.

Table 5.2 Output of VED analysis

Class	Number of items	% of No. of items	Usage value (In lakhs)	Criticality Scores
V	60	25.53	8.5	80-100%
E	123	52.34	8	40-80%
D	52	22.12	0.35	Below 40%

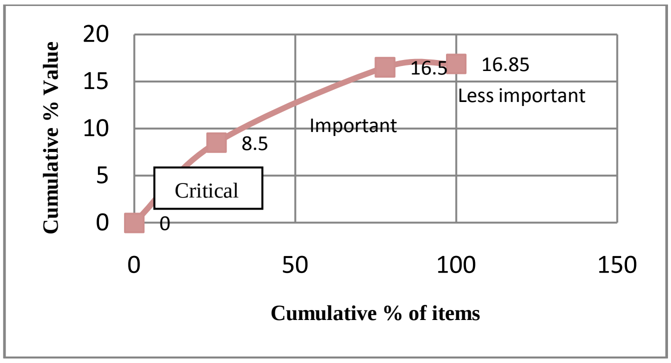

Fig. 5.2 Criticality analysis

The expert has given service levels based on criticality and consumption value is shown in Table 5.5. Using above equation and various service levels given in Table 5.3, the Table 4.1 can be re-calculated and shown in Table 5.4.

E. ABC-VED Groups matrix.

In case of spares, besides the criticality factor, the cost factor must also be taken into consideration, as can be seen from our study, where about 10% of the spares consumed about 70% of value.

Table 5.3 Service level for different combinations

	V	E	D
A	90%	76%	60%
B	96%	86%	70%
C	99%	96%	80%

This is the group requiring greater monitoring as it has fewer spares consuming most of the money. It was noted that not all the spares in this group were vital or essential. It also had spares from the desirable category. ABC-VED matrix model helps to narrow down on fewer spares requiring stringent control is shown in Table 5.5.

F. Result of 3D analysis

Items are classified on the basis of Usage value, Criticality and Lead time and then combined to give 3D matrix. Result of 3D analysis is shown in Table 5.6. The number of items in class A that is Vital and has long lead time is 4. Similar categorization is possible for items in each of the other cells. Using different K factor suggested in Table 4.3, each item in MUSIC-3D matrix can be calculated to get ideal stock level are shown in Table 5.7.

Table 5.4 Summary of ABC-VED Analysis

	V	E	D
A	Constant control and regular follow-up (AV)= μ_1=10; (1/13) Z_1 = 1.64 , X_1 = 12	Maintain at moderate level (AE) =6 Z_2 = 1.18, X=7	Eliminate item or keep nil stocks (AD)=6, Z_3 = 0.82, X = 6
B	Maintain at moderate level (BV)=15 Z_4 = 2.06, X = 18	Maintain at moderate level (BE)=47 Z_5 = 1.48, X = 54	Very low stocks (BD)=5 Z_6 = 1, X=6
C	Maintain at high level (CV) = 32 Z_7 = 2.65, X=41	Maintain at moderate level (CE)=70 Z_8 = 2.1, X= 85	Low stocks (CD)=14 Z_9 = 1.29, X=16

Table 5.5 ABC-VED Cumulative matrix.

Category	Groups	Total No. of items	% of No. of items	Usage Value (in Lakhs)
I	AV, AE, AD, BV, CV,	52	25	13.60
II	BE, CE, BD	142	68.26	2.7
III	CD	14	6.73	0.25

Table 5.6 MUSIC 3D matrix

Class	HCV		LCV	
	LLT	SLT	LLT	SLT
Critical	(1) 4	(2) 6	(3) 8	(4) 36
Non-Critical	(5) 5	(6) 18	(7) 26	(8) 72

G. Discussion of 3 D analysis

Items in cells 1,2,5,6 number around 16 % with annual consumption value of 87%, and remaining 84% account for an annual consumption of 13%. Cost reduction techniques are not used for items in cells 4,5,7,8 since the cost of cost reduction method is likely to be greater than the cost of the item itself. The cost reduction technique not applied to critical items falling in cells 1&2. Therefore cost reduction technique is applied only to items in cells 5& 6, which are 23 items.

H. Results of Simulation Model

For the selected value of ROL and ROQ, the programs iteratively calculate the total cost for various demands and lead time to give the grand total cost. The maximum iteration permitted is 50. The simulation model developed for the work is basically a MATLAB 2008 program that enables the user to find the best way to manage inventory.

Table 5.7 Summary of MUSIC-3D Matrix

Class	HCV		LCV	
	LLT	SLT	LLT	SLT
Critical	(1.8-2) (1) 4 1.8	(1.5-1.7) (2) 6 1.5	(2.5-3) (3) 8 2.5	(2.5-3) (4) 36 2.6
Non-Critical	(0.8-1) (5) 5 0.8	(0.5-0.8) (6) 18 0.5	(1.5-2) (7) 26 2	(1.5-1.8) (8) 72 1.8

The graphic user interface (GUI) for the inventory management tool designed is shown in Fig.5.3. The output of simulation that is total cost versus order quantity graph is shown in Fig. 5.4. From the graph minimum total cost and optimum order quantity is obtained, which can be used by the management for decision making.

VI. FINDINGS

In the ABC analysis it was found that, around 10.54% of the items occupy more that 70.19% of the usage value and around
71% of the items give 5% of the usage value. Criticality of the spares is the most important decision making criterion for the inventory control of spares. In this factory, items are not classified on the basis of their criticality. Therefore if there is a shortage for a critical item, production will be stopped. In the VED analysis, it was found that above 25.53% of the items are vital and hence they are critical for the production continuity. It is also found that around 22.12% of the items are non –critical. In the Control Matrix it was found that there are 13 items in AV category which are vital as well as of high usage value and 32 items in CV category.

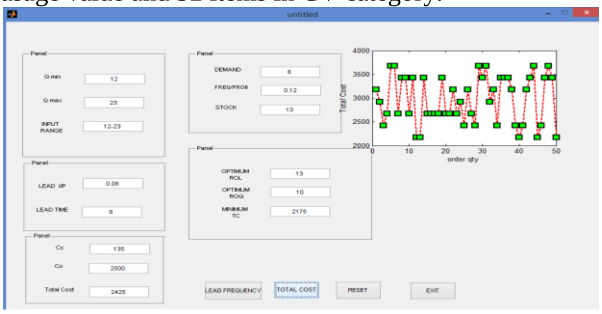

Fig. 5.3 The graphic user interface (GUI) for the inventory management tool

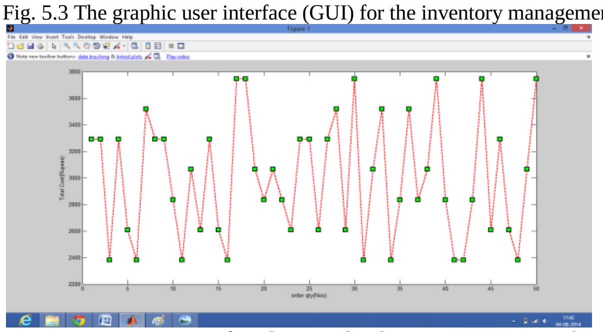

Fig 5.4 Output of total cost and order quantity curve graph

VII. RECOMMENDAIONS

Items in class A should be tightly controlled so that total cost can be reduced. Items in class B should be moderately stocked and liberal policy should be adopted for items in class C. VED analysis may be done for evaluating and assigning criticality scores for spares. Vital spares should be there in stock in order to avoid production stoppage. Simulation techniques have been used to handle the uncertainties in demand and lead time.

VIII. FUTURE SCOPE OF THE STUDY

This analysis was carried out for items in a single plant. This can be extended to other plants also. Similar analysis can be applied to other types of inventories like raw material. Technology used for the inventory management should be updated so that it can be made realistic. The information sharing programs and technologies will aid in inventory control system being more effective. The advantage of using a general-purpose programming language is that they offer greater flexibility in terms of being able to model more complex systems.

VIIII. CONCLUSION

The paper explains the use and application of selective inventory control technique of spares of a chlor-alkali Industry. The study was conducted in a chemical industry located at Ernakulum district. Many changes in technology have taken place in the processing of chemicals. From the literature it is understood that many old chemical processing industries are facing serious inventory problems. The major problems are due to lack of adopting new technologies in the inventory management system. Since the technology is old, inventory problems are high. The present analysis reveals that a systematic approach has been adopted to identify the inventory management problems of the chemical company and few suggestions are recommended to improve the existing inventory management system. The computer program is to calculate probabilistic demand and lead time for a given re-order level. Thus, by using this method, we are able to calculate future uncertainty in demand and lead time with optimum order quantity and minimum total cost.

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