Optimizing Inventory Carrying Cost and Ordering Cost Using Rank Order Clustering Approach for Small and Medium Enterprises (SMEs)

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Abstract

Inventory is one of the main assets for any organization, be it large enterprises or small and medium size enterprises. Therefore, decisions related to inventory directly affect the revenue generated by an organization. This work is intended to find a sufficient level of control over each inventory item and to alleviate inventory management issues of SMEs. In this paper, Rank Order Clustering (ROC) algorithm is used for aggregation of multi-item inventory items. Proposed framework is tested on a medium scale gear manufacturing firm which manufactures 40 different types of planetary and customized gear boxes. The results demonstrate 47.64 % of cost saving through proposed methodology of clusters formation using ROC and quantity discounts. This technique helps to identify various assemblies in order to aggregate requirement of components as well as to formulate specific inventory policy to cut inventory carrying cost for each component.

Key Words: - ***Rank Order Clustering algorithm, Multi item inventory classification, Small and Medium Enterprises (SMEs)***

I. INTRODUCTION.

In manufacturing sector, SMEs implement batch order production to fulfill requirements of their customers. Therefore, number of components to be handled varies significantly and therefore inventory management becomes very complex. Mismanaged inventory items may lead to significant financial problem for business organization which results in either excessive inventory or shortage. Inventory management helps enterprises to formulate policies to control inventories. Traditional methods for inventory item classification are; ABC analysis, XYZ analysis, HML analysis & VED analysis. Over a period of time number of different techniques for inventory item classification is proposed by authors. Details of such existing techniques are described in research background section.

This paper focuses on multi item inventory classification for effective inventory management. Rank Order Clustering algorithm is used as a tool to classify inventory items. Traditionally Rank Order Clustering algorithm is used in group technology. The approach in group technology is to identify machine groups with suitable group layout so that production of components with specific characteristics and similar operations become easier. The ROC algorithm rearranges rows and columns in an iterative manner that produces a matrix in which both columns and rows are arranged in order of decreasing value. The major advantage claimed for ROC over the other methods lies simply in its ability to deal easily with the problems of exceptional elements and bottleneck machines which frequently arise in practical problems. (J.R King-1980)

II. RESEARCH BACKGROUND

J.R King[1] (1980) was the first to invente clustering algorithm known as rank order clustering. King also demonstrated examples of exceptional elements (outliers) and the case of bottleneck machine. In conclusion, author described distinct advantages of ROC algorithm against single cluster analysis and bond energy method. M. P. Chandrasekharan[2](1986) et. al. presented extended version of well-known technique Rank Order Clustering algorithm. Author presented ROC algorithm with block and slide method and it was aimed to reduce deficiencies of ROC algorithm to a great extent, e.g. identification of bottleneck machines. Ernst[3] (1990) et.al. proposed clustering procedure namely operations related groups (ORGs) for inventory systems. In real manufacturing sector, there are thousands of stock keeping units which make it impossible to consider each and every item in developing inventory policies. Proposed procedure addresses statistical criteria (for homogeneity and discrimination) and operational performance of groups. Partovi[4] (1994) et.al. presented use of analytical hierarchy process for ABC analysis and emphasized on multiple criteria inventory item classification as in real manufacturing using Satty`s Analytical Hierarchy Process. Real data from pharmaceutical company are used in article to validate results and effectiveness of proposed method. R. Ramanathan [5] (2006) proposed classification method for multi-criteria inventory items using weighed linear optimization. There are many situations when apart from the annual use value, many other criteria become important in deciding the importance of an inventory item. This problem of multi-criteria inventory classification has been addressed by researcher in this paper. Bhattacharya [6] (2007) et.al. presented method for classifying inventory items namely, TOPSIS which considers the distances of each alternative from both the ideal and negative-ideal solutions. Simunovic[7] (2008) et.al. emphasized need for multiple criteria inventory classification. Author presented detailed comparison between traditional ABC inventory classification and advanced multiple criteria inventory classification through example. Krista [8] (2008) introduced k`-means algorithm which is modification of k-means algorithm. There is no need for pre-assigning the exact number of clusters in proposed method. Author has also demonstrated simulated experiments to confirm effectiveness of the proposed algorithm. Wan Lung Ng [9] (2007) presented a model that converts multiple criteria measures of an inventory item into a scalar score. The classification is based on the calculated scores using ABC principle. Peter [10] (2013) et.al. described various mathematical tools of different cluster analysis methods. Authors analyzed and compared hierarchical & non-hierarchical cluster analysis. Tomislav Saric[11] (2014) et.al. presented detailed comparison of three inventory classification techniques- multi criteria ABC analysis, Neural networks and Cluster analysis (K-means algorithm). Mehdi [12] (2015) et.al. proposed inventory classification method known as EDAS for multi criteria inventory classification, in which positive and negative solution, called positive distance from average and negative distance from average are considered. It is used for appraising alternative stock keeping units. Raja [13] (2016) et.al. proposed clustering classification of spare parts for improving inventory policies. Real data comprising of 612 spare parts were used to perform inventory classification. 11 variables were identified with the help of software as a basis for classification of spare parts. Danijela Pezer[14] (2017) analyzed various hierarchical clustering methods used namely, single linkage, complete linkage, weighted linkage and ward's method. After analyzing results, ward's method was chosen to interpret results by dendrogram as it aids in identifying clusters for inventory item classification. Author concluded effectiveness of hierarchical techniques in identifying optimal number of clusters. To validate results, k-algorithm was used. E. Balugani [15] (2018) et.al. presented K-algorithm and ward's method to cluster inventory items into homogeneous groups to be managed with specific inventory policies. Authors concluded that by clustering inventory items, there is no need for computationally expensive inventory system control simulations.

Clustering or group technology is aimed to categorize unlabeled data sets into groups of objects. Each group is called a "cluster" which consists of objects that are similar among themselves and dissimilar to other groups according to specific metrics. ROC has been implemented in many manufacturing firms to form machines cell formation in order to react as quickly as possible to meet altering customer demands and to enhance their productivity. To the best of our knowledge, there is no evidence in literature of using Rank Order Clustering for inventory management decisions.

III. DETAILSOFCURRENT STUDY

In this proposed work, Rank Order Clustering algorithm is aimed to classify inventory items for aggregation of an inventory items. Rank Order Clustering is traditionally used for grouping of machines but here it is used for cluster formation of inventory items for aggregation of requirement to optimize inventory carrying cost and ordering cost.

Extensive numerical analysis is carried out on a medium scale organization which manufactures planetary gear boxes and customized gear boxes to validate the results of proposed solution. Each gearbox assembly consists of number of components which varies from 14 to 55. Some components are manufactured in-house and some of them are purchased from suppliers. Therefore, the variety of inventory items to be controlled by organization is very large and difficult, especially when demand of gearbox assemblies varies over a period of time. The firm under organization does not follow any technique to classify inventory items. Procurement process of required items is carried out as and when requirement occurs which further results as shortages of required items or sometimes carries excess inventories. In order to get control over procurement practice, details of bought out parts for every gearbox assembly are collected. Table1 illustrates number of bought out components for each gearbox assembly.

Table-1: Number of components in gearbox assembly

Gearbox Assembly	No. of Bought out Components	Gearbox Assembly	No. of Bought out Components	Gearbox Assembly	No. of Bought out Components	Gearbox Assembly	No. of Bought out Components
1095	15	2130	26	3095	20	4095	13
1130	24	2160	25	3130	28	4130	25
1160	21	2190	25	3160	31	4160	30
1190	20	2230	25	3190	31	4190	27
1240	23	2240	32	3240	43	4240	27
1260	20	2260	40	3260	34	4260	26
1280	20	2280	39	3280	38	4280	29
1300	14	2300	29	3300	41	4300	34
1340	16	2340	28	3340	54	4340	43
2095	18	2380	37	3380	52	4380	41

IV. METHODOLOGY

Rank Order Clustering (ROC) has been studied by many manufacturing firms in order to respond as quickly as possible to meet demand variations as well as to boost their productivity. To the best of our knowledge, this is the first time in which ROC is aimed to form clusters of gear box assemblies in which similar components are being used. Purpose of applying ROC is to aggregate the total required quantity for reducing the total cost by optimizing ordering and inventory carrying cost. Incidence matrix has been formulated by considering type of gearbox assembly in column and bought out parts in row. Incidence matrix (40 x 180) for 40 gearboxes and 180 bought out components is constructed by filling binary values ‘0’ or ‘1’. If particular bought out component is required for particular gearbox assembly binary value ‘1’ is assigned, else binary value ‘0’ is assigned. Initial incidence matrix comprising gearbox assemblies in columns and its components in rows is constructed in MS Excel. Figure 1 shows initial components-assemblies matrix but as it is not possible to show the entire matrix, only few components-assemblies matrix is considered to illustrate the procedure of ROC.

Assembly No. ⇩	Allen Bolt 10x30	Allen Bolt 10x80	Allen Bolt 10x70	Allen Bolt 10x80	Ball Brg. 6212	Ball Brg. 6214	Ball Brg. 6216	Ball Brg. 6217	Ball Brg. 6218	Barrel nipple 1/4" BSP	Breather Plug 1/2" BSP	Breather Plug 1/4" BSP	Copper Washer M 8	Drain Plug 1/2" BSP	External Circlip A 20
1095							1			1			1		
1130	1			1				1		1		1		1	
1160										1					
1190						1									
1240		1	1						1				1		
1260		1	1								1				
1280	1			1											
1300	1					1				1					
1340					1										
2095										1					1
2130		1										1	1		
2160												1			
2190									1						1
2230	1		1			1					1				
2240			1										1		

Figure: 1- Initial Components Vs Assemblies matrix.

Finally, Rank Order Clustering algorithm is applied on incidence matrix in order to get grouping of gearbox assembly and bought out components. This approach is illustrated with stepwise procedure as given below.

Step-1 is performed on initial matrix by assigning binary weight to each column as per formula given. There are 180 components represented in each column, so binary value is assigned from 2^179 to 2^0 from right to left.

Step-2 is then performed by calculating decimal equivalent for each row as per formula.

Step-3 Rows are now rearranged in descending order of their decimal equivalent values.

Step-4 As there is rearrangement of rows, next step is performed next. Binary values ranging from 2^39 to 2^0 is assigned to rows from bottom to up as per step-4 of algorithm. (40 no. of gearbox assembly)

Step-5 Decimal equivalent for each column is calculated.

Step-6 Columns are rearranged in descending order of their decimal equivalent values. As there is rearrangement in columns, there will be second iteration of algorithm.

Steps 1 to 6 are repeated until there is no rearrangement in either rows or columns. Finally, algorithm stopped after third iteration. Once, Rank Order Clustering algorithm stops next step is to identify groups or cluster from final iteration.

Figure **2** shows the matrix after exchanging selected rows and columns with the application of ROC.

Assembly No ⇩	Allen Bolt 10x80	Ball Brg. 6212	Ball Brg. 6214	Allen Bolt 10x80	Copper Washer M 8	Allen Bolt 10x70	Ball Brg. 6218	Ball Brg. 6216	Allen Bolt 10x30	Breather Plug 1/4" BSP	Drain Plug 1/2" BSP	Ball Brg. 6217	External Circlip A 20	Barrel nipple 1/4" BSP	Breather Plug 1/2" BSP
1240				1	1	1	1								
1260				1		1				1					1
1095	1				1			1						1	
2240			1			1									
1340		1													
2095															
2190					1		1								
2130			1												
2160	1														
1300									1				1	1	
1160										1				1	1
2230				1		1			1		1				1
1280									1				1		
1130									1			1		1	1
1190			1								1				

Figure: 2- Final matrix

This above matrix helps purchase managers to identify the common components used in different assemblies and to aggregate the quantity required for ordering in larger quantities rather than ordering most frequently. The main purpose is to identify the common components and aggregate the demands of individuals.

This manipulation of the matrix for all the 180 components and 40 assemblies results into two distinct clusters with few outliers.

Table- 2: Cluster details.

Clusters	No. of Components	No. of gearbox assemblies
Cluster 1	100	24
Cluster 2	31	16
Outliers	43	-

As a result of final ROC matrix, assemblies 1280, 1300 and 2380 have been identified in which Allen Bolt 10x80 is being used.

Their requirements per period are summarized in table no-3.

Table-3: Assembly wise requirement in numbers.

Assembly No --->	1280	1300	2380
Apr	10	24	40
May	0	16	8
Jun	10	48	16
Jul	10	0	8
Aug	10	8	24
Sep	0	0	16
Oct	10	16	32
Nov	0	16	88
Dec	0	0	40
Jan	10	32	80
Feb	0	0	24
Mar	20	16	16

4.1.Existing purchase policy:-

In existing purchase policy, purchase manager follows lot for lot technique and executes separate orders for each assembly in each period. Purchase mangers have identified more than one supplier for each component and suppliers supply the same component at different prices. Therefore existing order policy results as higher ordering cost and sometimes stock-out situations. Sample calculations for assembly 1280 are shown below in table no-4

Table-4: Sample calculation to calculate cost required to purchase items assembly-wise.

Existing order quantity per period	Ordering cost	Procurement cost
10	150	327
0	0	0
10	150	327
10	150	327
10	150	327
0	0	0
10	150	327
0	0	0
0	0	0
10	150	327
0	0	0
20	150	653
	Total:-	3664/-

Likewise, it costs Rs. 6950/- and 14907/- to purchase required quantity of Allen Bolt 10x80 for assembly number 1300 and 2380 respectively. Therefore in existing policy, total cost required for procuring total quantity is Rs. 25221/-

4.2.Proposed method for reducing unit price.

Application of proposed model is illustrated with the same numerous multi-period, single-item, lot-sizing problem to find an optimal solution over the entire planning horizon of one year.

Item: Allen Bolt 10x80.

Supplier wise price details are given below in table no-5.

Table-5: Supplier wise price details.

Suppliers of Allen Bolt 10x80	Price/unit.
Om Sai Enterprises	17.6
Southern Engineers	25.03
OmSales	32.67

Application of ROC helps to identify the assemblies consisting of Allen Bolt 10x80 and to aggregate the quantity required per period in three assemblies. Aggregated quantity of Allen Bolt 10x80 per period is given in the table no-6.

Table-6: Aggregated quantity of Allen Bolt 10x80 per period.

Assembly No --->	1280	1300	2380	**Total aggregated quantity required per period.**
Apr	10	24	40	**74**
May	0	16	8	**24**
Jun	10	48	16	**74**
Jul	10	0	8	**18**
Aug	10	8	24	**42**
Sep	0	0	16	**16**
Oct	10	16	32	**58**
Nov	0	16	88	**104**
Dec	0	0	40	**40**
Jan	10	32	80	**122**
Feb	0	0	24	**24**
Mar	20	16	16	**52**

Now purchase managers can order aggregated quantity of three assemblies in single order rather than ordering thrice. This will help to order the total quantity in single order at least cost offered by suppliers which will result as cost benefits as shown in table no-7.

Table-7: Cost benefits using quantity discounts.

Quantity to be ordered after aggregation	**Ordering cost**	**Procurement cost**
74	150	1302.4
24	150	422.4
74	150	1302.4
18	150	316.8
42	150	739.2
16	150	281.6
58	150	1020.8
104	150	1830.4
40	150	704
122	150	2147.2
24	150	422.4
52	150	915.2
	Total:-	13205

With the application of ROC and quantity discount, it costs Rs 13205 to purchase the same quantity as in case of existing system. This approach can save 47.64% of total annual cost to purchase the same quantity of Allen Bolt 10x80. The same concept can be applied to remaining 179 components to calculate the overall cost savings per annum.

V. CONCLUSION.

The insights derived from above numerical analysis illustrate 47.64 % potential savings for multi-period, single-item, lot sizing problem with the application of ROC. This percentage will increase with increase in quantity. In existing purchase policy, individual orders were being placed to purchase required quantity of each component with no inventory policy. With the application of ROC, different assemblies consisting of similar components were identified. This resulted into aggregation of components which further resulted into reducing inventory and ordering cost drastically. As quantity increases, suppliers can be asked for further quantity discounts.

This work can be extended with application of lot sizing techniques to form inventory policies for SMEs to scale their inventories up or down as per situation and to get further more quantity discounts.

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