AN APPLICATION OF FUZZY COGNITIVE MAPPING IN OPTIMIZATION OF INVENTORY FUNCTION AMONG AUTO COMPONENT MANUFACTURING UNITS IN SME SECTOR

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1.0 ABSTRACT

Optimization of inventory quantity is a vital issue among the manufacturer and supply chain. Optimization is a complex task due to classification of inventories on the basis of cost and due to dynamic movement behavior of various inventories in the supply chain. The primary objective of the present paper is to develop the optimization model for the 2D criteria base classified stocks in the SMEs working in the auto component manufacturing industry. The matrix is framed by combining three ranges of cost and three types of movement behavior. A 3 X 3 matrix is frame and the cells were responding as Ax, Ay,Az, Bx,By,Bz and Cx,Cy, Cz. The critical cost is identified and the basis of the same models was fixed. Node’s importance or cognitive or conceptual gives an indication of the importance that the node by measuring the degree. The importance of the node is evaluated as Imp (i) = in (i) + Out (i).

The present study identified that, the inventory cost in auto component manufacturing industries is influenced by the variables like, Purchase Cost of the components (Base cost= Vendor invoice cost + order costs), Easy to carry and fix, Strength and weightage of the materials as components, Brand image of the components purchased from outside from the SMEs, Availability of suppliers for components, Safety and reliability, Design and appearance the component. The optimization can be done on the basis of design and development of the inventory function strategy applicable to the independent firms based on the nature of products, size of operations and financing capacity.
Key words: Inventory cost-dynamic behaviour-fuzzy cognitive mapping-vital variables-optimization.

1.1 INTRODUCTION

Optimization of inventory quantity is a vital issue among the manufacturer and supply chain. Optimization is a complex task due to classification of inventories on the basis of cost and due to dynamic movement behavior of various inventories in the supply chain. The present paper in focused on finding a unique optimization model considering and classifying the inventories in a 2 D matrix. The primary objective of the present paper is to develop the optimization model for the 2D criteria base classified stocks in the SMEs working in the auto component manufacturing industry. The 2D Criteria is developed by combining the two basic elements relating to inventory cost among the industries. They are Value of the inventory and other one is consumption behaviour/issue behaviour/movement behaviour of different inventories. The term inventory includes basic raw materials, work in progress and the finished goods. In majority of the SMEs in auto component manufacturing sector, the number of components is high in number in terms of basic inventories, work-in-Progress inventory and finished components.

Another significant observation made among the SMEs is the proportion of selected inventories to total inventory cost is high in Ax, Ay and Az stocks. A survey report says the composition of inventory cost of these stocks (Ax+Ay+Az) to total inventory cost is 70 percentage across the sector. This made us to think to focus on these stocks and to optimize them in order to control the total inventory costs. Based on this assumption we have developed a 2D Matrix and fixed the definite area to focus for optimization.

Matrix showing the Classification of Inventory based on 2D model

<table>
<thead>
<tr>
<th>Value of inventory</th>
<th>Quantity of consumption of inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>X  y  z</td>
</tr>
<tr>
<td>Ax</td>
<td>Ay  Az</td>
</tr>
<tr>
<td>B</td>
<td>Bx  By  Bz</td>
</tr>
<tr>
<td>C</td>
<td>Cx  Cy  Cz</td>
</tr>
</tbody>
</table>

The unique feature of this model is identifying and classifies the intensity and impact of stocks on the basis of cost and quantity. It also involves segregation of high sensitive and low sensitive inventories in term of total cost of an inventory and the hidden cost due to over stock. Therefore a unique model may not be suitable for the entire range of inventories, Hence, two fold approach is followed and at that basis simple and practical models are developed and empirically validated on the SME`s in the sample area.

1.2 REVIEW OF LITERATURE

Cognitive Mapping (CM) model were introduced by Axelrod in the late 1970’ and were widely used for analyzing the sociological problems and decision making in
sociological problems. The introduction of fuzzy logic give new representing capabilities to CM’s and led to development of Fuzzy cognitive maps (FCM) by kosioko in the late 1980’s. FCM create models as collections of concepts and the various casual relations that exists between these concepts. The concepts are represented by nodes and the causal relationships by directed arcs between the two nodes. Each arc is accompanied by a weight which defines the degree of relation between the two nodes. The sign of the weight the positive or negative or casual relation between the two concept nodes.

1.3 METHODOLOGY

Inventory models will have dynamism and probability behavior in general. Combination of cost and movement behavior is Hyper dynamic in nature. This was observed by physical verification of cost and movement behavior of Hyper dynamic in nature. This was observed by physical verification reasons of the 416 SMEs in the Auto hub area. The physical verification of inventory data base is taken to the study. Finally a two dimension (2D) matrix is constructed by considering cost and inventory moment of the stocks. The matrix is framed by combining three ranges of cost and three types of movement behaviour. A 3 X 3 matrix is frame and the cells were responding as Ax, Ay,Az, Bx,By,Bz and Cx,Cy, Cz. The critical cost is identified and the basis of the same models was fixed. FCM create models as collections of concepts and the various causal relations that exist between these concepts. The concepts are represented by nodes and the causal relationships by directed arcs between the nodes. Each arc is accompanied by a weight which defines the degree of relation between the two nodes. The sign of the weight the positive or negative or zero causal relation between the two concept nodes.

1.4 Development of FCM Models in the study about problems faced by SMEs in the sample area.

The reliability of an FCM model depends on whether its construction method follows rules that ensure its reliability. Since the model is created by the personal opinions and points of view of the experts on the specific topic, the reliability of the model is heavily depended on the level of expertise of the domain experts. These are two main methods for the construction of FCM’s:

1. The documentary coding method which involves the systematic encoding of Documents that represents the assertions of specific topic.
2. The questionnaire method which involves interview and filling in a questionnaires by domain experts.

In our case we used the second method, discussion, interviewing, analyzing and also supplying with questionnaires to a domain expert. The domain expert providing the actors and factors, the possible alternative scenarios as well as the analysis of the findings.

1.5 NEED FOR THE STUDY

There are several reasons manufacturers are increasing focus on optimizing inventory by applying the latest tools and techniques for inventory control. Traditionally
competitive pressure has always driven Manufacturers to seek enhanced capabilities to reduce inventory levels and to enhance service levels and supply availability; and to establish the right product inventory mix and level in each geography and channel. Many manufacturers also focus on inventory as part of shifting their operations to achieve demand-pull replenishment across their supply network – hoping to achieve the performance demonstrated by leading manufacturers.

A key driver of the renewed focus on inventory lies in the recognition that traditional techniques are failing to reign in inventories in the wake of increased supply chain complexity. This complexity is characterized by increased uncertainty. Demand is more volatile and therefore less predictable. This is true not only for aggregate demand but for forecasting splits and volumes across channels and markets. Traditionally, three strategies have been employed by manufacturers to address uncertainty:

a) Increase inventory levels to hedge against uncertainty.
b) Develop supply chain flexibility to be more responsive to uncertainty.
c) Improve forecast accuracy so that less uncertainty propagates to the manufacturing floor. Inventory optimization techniques and technologies map to the flexibility and accuracy strategies.

Globalization is one big drive, the evolution of emerging markets such as China and India present new challenges in effective product distribution with low inventory levels. Globalization of supply networks means that key functions such as R&D, product design and manufacturing are now geographically spread out, which hampers inventory reduction efforts, that are often best executed by a cross function team working together very closely. Increased rates of new product introduction and product innovation are also driving complexity into supply networks. Finally, SMEs need to have customized strategy for the different kinds of inventory they deal with. It can help in controlling the total cost and optimizing success of the organizations.

1.6 INVENTORY OPTIMIZATION DEFINED

Inventory Optimization (IO) is the application of a range of latest techniques and technologies for improving inventory visibility, control, and management across an extended supply network. These techniques and technologies are driving improvements beyond what traditional inventory management techniques - even advanced techniques - have been able to deliver IO Techniques.

IO techniques apply rigorous and discrete analysis to analyzing inventory performance. They use the analysis to identify product specific changes to inventory stocking and replenishment policies; to identify the supply network configuration or, to correlate inventory investments to item revenue or profit generation. On the planning side, a key inventory optimization technique is profit-driven analysis, where the profit each individual product contributes is ranked. Expanding the use of collaborative and demand pull replenishment scheme such as a vendor – or supplier –managed inventory
to drive highly precise replacement and fulfillment activity. These techniques are also benefiting from improved supply chain planning and control. Lean seeks to optimize inventory by driving out non-value added inventory management tasks in the factory or warehouse and by improving planning and control a granular level across each manufacturing or distribution step.

1.7 Variables Identified

On the basis of review of literature and stock records verification and observation among the SME’s, the following 15 attributes are taken as major components influencing the inventory cost in the supply chains.

S1: Purchase Cost of the components (Base cost= Vendor invoice cost +order costs)
S2: Easy to store/preserve of basic components bought and manufactured (Because some materials will be bought in the form of RM, WIP and FG)
S3: Easy to carry and fix: Material handling costs are also vital in inventory issue cost. Handling equipments, repairs and usability of the same are also important determinants in inventory costs.
S4: Strength and weightage of the materials as components
S5: Brand image of the components purchased from outside from the SMEs
S6: Availability of suppliers for components required in the process of manufacturing the other component with suitability and flexibility.
S7: Safety and reliability of the component of the equipments bought from different suppliers.
S8: Design and appearance the component (Design plays a major role in terms of suitability for all the models and all brands developed).
S9: Multiplicity of uses of the same component
S10: Alternatives availability for all the types of inventory.
S11: Mode of packing and transport of the raw materials, WIP and Finished goods.
S12: Reparability and reuse of the component in case of damages in transport.
S13: Carrying costs (Interest charges payable on the funds blocked / charged by the supplier for the credit period)
S14: Transport costs (From the vendor place to store and consumption point)
S15: Legal costs (In case of inter state / import of materials or components/ taxes levied)
1.8 Application for using FCM model

The adjacency matrix for the problem is:

**FCM MATRIX FOR THE INVENTORIES**

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<tr>
<th>Factors</th>
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Diagram: 1.0: Showing the relationship between the variables influencing total inventory costs in supply chains are presented below:
1.9 STATIC ANALYSIS

The static analysis of the model is based on studying the characteristics of the weighted directed graph that represent the model, using graph theory techniques. The first way to examine statically the models graph is by calculating its density. The density `d` is given by \( d = \frac{m}{n(n-1)} \) where \( m \) is the number of arcs in the model and \( n \) is the number of concepts of the model. Product \( n(n-1) \) is equal to the maximum number of arcs that a graph of \( n \) nodes can have. Density give an indication of the complexity of the model. High density indicates increased complexity in the model and respectively to the problem that the model represents. For this problem \( d = \frac{104}{(15)(14)} = 0.5 \) which indicate the complexity of the problem.

Graph theory also provides the nodes importance that assists the static analysis of FCM models. Node’s importance or cognitive or conceptual gives an indication of the importance that the node by measuring the degree. The importance of the node is evaluated as \( \text{Imp}(i) = \text{in}(i) + \text{Out}(i) \).

Where \( \text{in}(i) = \text{number of incoming arcs of the node } i \)
\( \text{Out}(i) = \text{number of outgoing arcs of node } i \)

According to this definition, the importance of the nodes of the FCM model is given by

<table>
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<td>Total</td>
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<td>5</td>
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</tbody>
</table>

It is found the most central or important concepts were S1,S3,S4,S5,S6,S7,S8
2.0: DYNAMIC BEHAVIOUR

If S1 is on then, S1, S2, S3, S4, S7, S8, S10, S13, S14 are on and S5, S15 becomes negative.

This means to say that the S1- Purchase cost of the components is associated with the
S2: Easy to store/preserve of basic components bought and manufactured (Because some materials will be bought in the form of RM, WIP and FG)
S3: Easy to carry and fix: Material handling costs are also vital in inventory issue cost. Handling equipments, repairs and usability of the same are also important determinants in inventory costs.
S4: Strength and weightage of the materials as components
S7: Safety and reliability of the component of the equipments bought from different suppliers.
S8: Design and appearance the component (Design plays a major role in terms of suitability for all the models and all brands developed).
S10: Alternatives availability for all the types of inventory.
S13: Carrying costs (Interest charges payable on the funds blocked / charged by the supplier for the credit period)
S14: Transport costs (From the vendor place to store and consumption point)

Represented as:
If S2 is on
B1 = [0,1,0,0,0,0,0,0,0,0,0,0,0,0,0]

B1*E = B2 = [1 0 1 0 0 0 0 1 1 0 1 0 0] ---- B2 = [1,1,0,1,0,0,0,1,0,1,0,1,0,0]
B2*E = B3 = [2 5 3 0 -1 3 2 0 1 2 0 1 2 3 0] ---- B3 = [1,1,1,0,0,1,1,0,1,1,0,1,1,1,0]

B3*E = B4 = [2 3 3 5 -2 -1 0 5 -1 4 0 1 4 2-1] --- B4 = [1,1,1,1,0,0,0,1,0,1,0,1,1,1,0]
B4*E = B5 = [2 5 4 3 -3 0 1 2 1 3 1 -1 4 2 -1] --- B5 = [1,1,1,1,0,0,1,1,1,1,0,1,1,1,0]
B5*E = B6 = [3 6 6 3 -2 0 2 4 0 2 -1 1 3 3 0] --- B6 = [1,1,1,1,0,0,1,1,0,1,0,1,1,1,0]
B6*E = B7 = [3 5 5 4 -2 0 1 3 0 4 1 0 4 2-1] --- B7 = [1,1,1,1,0,0,1,1,0,1,0,1,1,1,0]

Therefore S2 is on then, S1, S3, S4, S7, S8, S10, S13, S14 are on and S5, S15 becomes negative. This means to say that the S2- Ease to store and preserve the components is associated with the

S1- Purchase cost of the components
S3: Easy to carry and fix: Material handling costs are also vital in inventory issue cost.

Handling equipments, repairs and usability of the same are also important determinants in inventory costs.

S4: Strength and weightage of the materials as components
S7: Safety and reliability of the component of the equipments bought from different suppliers.

S8: Design and appearance the component (Design plays a major role in terms of suitability for all the models and all brands developed).
S10: Alternatives availability for all the types of inventory.
S13: Carrying costs (Interest charges payable on the funds blocked / charged by the supplier for the credit period)
S14: Transport costs (From the vendor place to store and consumption point)

The second rotation concluded with static behaviour of the attributes with the same association between the attributes. Hence, we will be discussing the casual relation between the important nodes S1, S3, S4, S5, S6, and S8.

Similarly if S15 is on S1S2, S3, S4, S5, S6, S7, S8, S13 and S14 are all on.

Next we will discuss the causal relation between the important nodes S1, S3, S4, S5, S6, S7, and S8.

The adjacency matrix is given by:

\[
\begin{bmatrix}
S1 & S3 & S4 & S5 & S6 & S7 & S8 \\
S1 & 0 & 0 & 0 & -1 & 1 & 1 & -1 \\
S3 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \\
S4 & -1 & 1 & 0 & -1 & 0 & 1 & 0 \\
S5 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\
S6 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\
S7 & 1 & 1 & 1 & 1 & 0 & 0 & 1 \\
S8 & 1 & 1 & 0 & 1 & 0 & 1 & 0
\end{bmatrix}
\]

Suppose If S1 is on then A = \([1,0,0,0,0,0,0]\\)
\[A1 = [0,0,0,-1,1,1,1] \quad \ldots \quad A1 = [1,0,0,1,0,0,0]\\]
\[A2 = [-1,0,0,1,0,0,0] \quad \ldots \quad A2 = [1,0,0,1,0,0,0]\]

If S1 is on S5 is on

Suppose If S3 is on then B = \([0,1,0,0,0,0,0]\\)
\[B1 = [1,0,1,-1,-1,0,1] \quad \ldots \quad B1 = [1,1,1,0,0,1,1]\]
\[B2 = B1*E \\
B2 = [2,3,1,-1,0,1,1] \quad \ldots \quad B2 = [1,1,1,0,0,1,1]\]

If S3 is on S2, S3, S6, S7 is on

If S4 is on then C = \([0,0,1,0,0,0,0]\\)
\[C1 = C*E \\
C1 = [-1,1,0,-1,0,1,0] \quad \ldots \quad C1 = [0,1,1,0,0,1,0]\\]
\[C2 = C1*E \\
C2 = [1,2,2,0,0,1,1] \quad \ldots \quad C2 = [1,1,1,0,0,1,1]\]
\[C3 = C2*E \\
C3 = [2,3,1,-1,0,1,1] \quad \ldots \quad C3 = [1,1,1,0,0,1,1]\]

If S4 is on then S1, S3, S7, S8 is on
If S5 is on then $D = [0,0,0,1,0,0,0]$ 

$D_1 = D \times E$  

$D_1 = [1 \ -1 \ 1 \ 0 \ 1 \ 1 \ 1]$ ...... $D_1 = [1,0,1,1,1,1,1]$  

$D_2 = D_1 \times E$  

$D_2 = [1 \ 2 \ 1 \ 1 \ 2 \ 3 \ 2]$ ...... $D_2 = [1,1,1,1,1,1,1]$  

$D_3 = D_2 \times E$  

$D_3 = [2 \ 2 \ 2 \ 0 \ 1 \ 3 \ 3]$ ...... $D_3 = [1,1,1,1,1,1,1]$ 

If S5 is on then S1,S3,S4,S6,S7,S8 is on 

If S6 is on $F = [0,0,0,0,1,0,0]$  

$F_1 = F \times E$  

$F_1 = [-1 \ 0 \ 0 \ 1 \ 0 \ 1 \ 1]$ ...... $F_1 = [0,0,0,1,1,1,1]$  

$F_2 = F_1 \times E$  

$F_2 = [2 \ 1 \ 1 \ 3 \ 1 \ 3 \ 3]$ ...... $F_2 = [1,1,1,1,1,1,1]$  

$F_3 = F_2 \times E$  

$F_3 = [2 \ 2 \ 2 \ 0 \ 1 \ 3 \ 3]$ ...... $F_3 = [1,1,1,0,1,1,1]$  

$F_4 = [1 \ 3 \ 1 \ 0 \ 0 \ 2 \ 2]$ ...... $F_4 = [1,1,1,0,1,1,1]$ 

If S6 is on then S1,S3,S4,S6,S7,S8 is on 

If S7 is on $G = [0,0,0,0,0,1,0]$  

$G_1 = G \times E$  

$G_1 = [1 \ 1 \ 1 \ 1 \ 0 \ 0 \ 1]$ ...... $G_1 = [1,1,1,0,1,1,1]$  

$G_2 = G_1 \times E$  

$G_2 = [3 \ 2 \ 2 \ -1 \ 1 \ 2 \ 2]$ ...... $G_2 = [1,1,1,0,1,1,1]$  

$G_3 = G_2 \times E$  

$G_3 = [1 \ 3 \ 1 \ 0 \ 0 \ 2 \ 2]$ ...... $G_3 = [1,1,1,0,0,1,1]$  

$G_4 = G_3 \times E$  

$G_4 = [2 \ 3 \ 1 \ -1 \ 0 \ 1 \ 1]$ ...... $G_4 = [1,1,1,0,0,1,1]$ 

If S7 is on S1,S2,S3,S6,S7,S8 is on 

If S8 is on $H = [0,0,0,0,0,0,1]$  

$H_1 = [1,1,1,1,0,1,0,1,0,1,0,1,0]$ ...... $H_1 = [1,1,0,1,0,1,1,1]$  

$H_2 = [4,1,2,0,1,1,2]$ ...... $H_2 = [1,1,1,0,1,1,1]$  

$H_3 = [1,3,1,0,0,2,2]$ ...... $H_3 = [1,1,1,0,0,1,1]$  

$H_4 = [2,3,1,-1,0,1,1]$ ...... $H_4 = [1,1,1,0,0,1,1]$ 

If S8 is on S1, S2, S3, S7 

Therefore it is identified that, the variables influencing inventory cost in dynamic behavior and static behavior is one and the same.

3.0 SUMMARY

Inventory problem is universal in nature. But the solutions for the same are multiple. The selection and application to address the issue is purely depends on the independent firms in the industry. In the auto component industry is basically featured
with SME nature in the sample area. The present study identified that, the inventory cost in auto component manufacturing industries is influenced by the following variables.

S1: Purchase Cost of the components (Base cost= Vendor invoice cost + order costs)
S3: Easy to carry and fix: Material handling costs are also vital in inventory issue cost. Handling equipments, repairs and usability of the same are also important determinants in inventory costs.
S4: Strength and weightage of the materials as components
S5: Brand image of the components purchased from outside from the SMEs
S6: Availability of suppliers for components required in the process of manufacturing the other component with suitability and flexibility.
S7: Safety and reliability of the component of the equipments bought from different suppliers.
S8: Design and appearance the component (Design plays a major role in terms of suitability for all the models and all brands developed).

The optimization can be done on the basis of design and development of the inventory function strategy applicable to the independent firms based on the nature of products, size of operations and financing capacity. No unique policy can be suggested to all due to heterogeneity in the product nature and capacity of the firms. However the critical factors influencing inventory cost is common. A common problem addresses by different firms in the industry is possible through customization of standard techniques. For these firms has to come forward with commitment and intention to change the existing climate. This can resolve the inventory optimization in a better way in the years to come.

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