

Quantification of the benefits of applying Vendor Managed Inventory for a manufacturer using graph theoretic approach

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Abstract: Vendor Managed Inventory is a planning and manufacturing system wherein the vendor has the responsibility of replenishing the inventory depending on the information that is shared between the supplier/vendor and the retailer. Though this has proven to be successful inventory management system by big giants in the market but the small scale industries are still struggling to achieve the desired targets. In our study we tried to quantify the benefits of VMI on a particular small auto parts manufacturing industry. The research quantified the present benefits using Graph Theoretic Approach and also figured out further scope for improving the benefits.

Keywords — Vendor Managed Inventory, Graph theoretic approach

I. INTRODUCTION

The current competition in the market and complex supply chains led to use of many policies and management-systems. VMI (vendor managed inventory) is also such a tool. It can also be referred as inventory management system controlled by supplier. The entire responsibility of managing inventory at the customers end is taken by the vendor/supplier. By using any of the available data interchange method, the supplier gets all information about the limits within which the inventory should be maintained. It also improved the efficiency of flow of materials in a supplier and retailer partnership. This collaborative approach ensures management, continuous replenishment and process coordination. In order to apply this technique an in-depth view of factors that are useful in successful implementation is required. There are only few studies done in quantification of process, generally fluctuations in cost are given importance in case studies conducted. Many companies achieved benefits initially but later struggle to maintain cost benefits. This study will be useful for those who intend to apply the Vendor Managed Inventory process.

II. BACKGROUND OF STUDY

Vendor Managed Inventory has proved its success for big supply chains. Vendor Managed Inventory and Consignment Inventory gained popularity in India in the last decade, many big entrepreneurs adopted it in their business houses also. The studies still say that generally businesses derive 30-40% of the benefits. The small business houses in India still struggle to know the actual benefits they can obtain from Vendor Managed Inventory. The small scale manufacturers don't know the benefits they should target and achieve long term benefits. Our study relates more with

the benefits of Vendor Managed Inventory for those who are in the process of adopting Vendor Managed Inventory. We analyzed the various factor involved in VMI and through interviews with professionals and entrepreneurs, We listed the factors and categorized them in three broad categories that play the most important role in achieving all the benefits of VMI. In this work we tried to quantify the benefits of these thoroughly researched benefits.

III. LITERATURE REVIEW

Faisal et al [5] calculated the quantification of risk factors of supply chain using the digraph and matrix method. It also provides opportunity to integrate new variables that impact the risk mitigation environment of overall supply chain. Graph theoretic approach is also used for Total Quality Management evaluation of an industry [9] and for assessing the role of human factors in quality management[10]. Researchers used Graph theoretic approach to calculate the quality dimension of web 2.0. The purpose of the paper is to present the single numerical value for, "website quality dimension in 2.0 environment"[22]. Researchers [3][4] used this graph theory approach for calculating performance of compacting die manufactured by wire EDM. They considered the "surface characteristics and dimensional accuracy" as an important attribute for judging the performance of a compacting die. The performance indexes were under combination of various factors/sub factors that evaluate the influence of factors considered. They also used GTA to evaluate the machinability of tungsten carbide composite with wire EDM. Material removal rate is considered important here. Some researchers used it for selection of industrial robots by comparing their various features [15] and few used this for selection of automobile vehicles [16]. It is also used for evaluation and quantification of quality of gas turbine system by assessing

the various quality factors [18], for analyzing and modelling a combined cycle power plant [19,20], measuring the flexibility in manufacturing system [2], a decision making model for Flexible Manufacturing system [13].

IV. CLASSIFICATION OF FACTORS

There are many factors which a small scale manufacturer must care for while applying Vendor Managed Inventory. We have tried to quantify the benefits in three main categories. The factors that we listed in three categories are chosen after experts interviews and researchers view:

| S. No. | Categories | Sub factors |
|--------|-------------------|--|
| I | Decisive factors | <ul style="list-style-type: none"> Better customer service Efficiently managed supply chain Timely delivery of products Improved sale Increased trust among supplier/customer |
| II | Operative factors | <ul style="list-style-type: none"> Planned production Better management of goods Decreased storage area Increased reliability on supplier Better documentation Better prediction of sales. |
| III | Budgeting factors | <ul style="list-style-type: none"> Decreased transportation cost Decreased inventory holding costs Reduced product cost |

Table 1

Decisive Factors: These are the deciding factors that will decide the overall impact of benefits of VMI on the industry that we have chosen. These are categorized as per discussions with experts. The beneficial factors included in this subhead are:

- Better customer service: Customer satisfaction is the most important determinant of success of Vendor Managed Inventory. It is therefore topmost in decisive factors.
- Efficiently managed supply chain: The success of any of the inventory management methods is best measured by the efficiency of its supply chain. So this helps in determining the success of the process.
- Timely delivery of products: Customer satisfaction is very much dependent on timely delivery of products. In present market, customers do not want a long waiting period, they generally go for another product. It actually proves that the supply chain is in proper coordination.
- Improved Sales: One of the important factors that determines the success of VMI process is the increase in sales. It brings more cost benefits also.

Increased sales proves that the whole process is going in right direction.

- Increased trust among supplier/customer: Winning trust of customers is more difficult than increasing sales of the industry. Sustainable growth of any industry can be achieved only when trust relationship is there. This factor is generally ignored in studies as a company needs to value each customer for achieving trust value in market.

Operating factors: These are significant factors in the whole VMI process. This category is formed of those factors that play a vital role in success of VMI. Vendor Managed Inventory will not be able to achieve any cost benefits if these are ignored.

- Planned production: More planned is the process of production, more organized is the supply chain network. Without planning it will result in overstock only. A firm can face huge financial losses if the planning process is not updated.
- Better management of goods: Goods manufactured and their handling is again a key factor for deriving benefits of VMI for an industry.
- Decreased storage area: One of the most significant factors for VMI. This factor yields to decreased inventory holding costs. Storage area and its rent etc. make a major component of inventory costs.
- Increased reliability on suppliers: Without sharing a reliable relationship, neither the supplier nor the retailer can achieve success in this information sharing process.
- Better Documentation: Better Management and Documentation are interrelated to each other. They show interdependence too. This factor resolves all the financial issues between the supplier and retailer.
- Better prediction of sales: Very detrimental factor for achieving timely production and delivery of products at the customer's end. This factor can't be ignored in the list of significant factors.

Budgeting Factors: These factors are directly related to the money matters. The major sub factors in this category are:

- Decreased transportation cost: The cost of transportation can be reduced significantly by choosing a suitable VMI process. In some of the VMI agreements, this cost is shared between suppliers and retailers. Both parties receive the benefits in due course of time.
- Decreased inventory holding costs: As one of the major component of inventory costs is involved in holding/maintaining right amount of inventory. So,

this factor plays an important role in budgeting factors.

- (iii) Reduced product cost: This reduction in cost is very much related to implementation of operative factors. This again contributes towards the financial matters of a company.

V. GRAPH THEORY

Graph theory has proved itself in many fields of science and technology like mathematics, chemistry, physics, economics, operation research, linguistics etc. it has played an important role in network analysis, diagnosis, functional representation etc. It is closely related to various branches of Mathematics including matrix theory, group theory, probability, topology and combinatorics.

Graph theoretic approach (GTA) is better than many of the other analysis methods as

- It gives a simple numeric value to all the factors [5][6].
- It cares for the directional relationship and interdependence among the factors and its various sub factors.[3][5]
- It is a very systematic approach for converting qualitative factors in to quantitative values.[6][5]
- GTA allows computer processing as well as visual analysis of factors involved.[5][3]
- It allows comparison between different organizations and also self-analysis.[1][6]

Using these features of GTA, authors have tried to quantify the benefits of vendor managed inventory on an industry and provided a platform for self-analysis.

The benefits of VMI depends upon the inheritance of different factors that influence the VMI Process. These are modeled by a network of factors and interactions between them. These are represented in the form of a digraph. The factors are classified in to three categories and the benefits of VMI are found in “BOV”, measuring how much benefits are obtained by the use of VMI.

Main objective is establish correlation between the three categories of factors and their quantification. For this the quantification is done based on their sub-factors and interdependent relationships that they share through graph theoretic approach.

The main components are:

- Directed graph [1] [3]
- Representation in matrix form [1] [4]
- Representation of permanent function. [1][2]

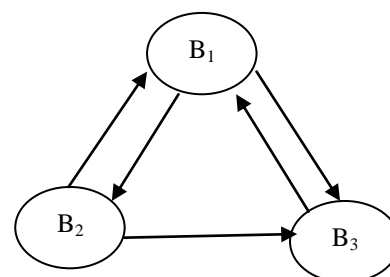
The directed graph benefits us to look at the interdependencies between the factors. The matrix converts these interdependencies in mathematical form and helps us to calculate the ‘BOV’ value.

A methodology for evaluation of BOV for an Industry is proposed through the basis of GTA.

Main Step involved in this process are:

- The factors that help a company gain from VMI in terms of list of management benefits are listed. These are obtained after interviews with experts and researchers in this field.
- Based on these, a diagram is formed which considers all the factors and their interdependence. The three major heads identified will become the nodes. And the direction of the edges gives their interdependence.
- A diagram is develop b/w the sub factors depending on the linkage among them.
- From this, a matrix is developed. It is a $m \times m$ matrix, where the diagonal element represent sub-factors and off diagonal elements represent the interactions b/w them.
- Now calculation of ‘permanent function’ is done.
- Develop the BOV matrix calculating the benefits from the digraph.
- Value of permanent function at each sub-factor level provides inheritance for each factor, it is again decided after discussions with experts.
- Now calculate the permanent function ‘BOV’, which quantities all the VMI benefits.

Formation of digraph: A directed graph or digraph is used for representing the variegated factors and their mutual interdependence. It consists of set of nodes $B = \{B_i\}$ with $i = 1, 2, 3, \dots, M$ and a set of edges $B = \{b_{ij}\}$. Node B_i will represent the i th factors and its edges will represent interdependencies between the factors. The number of nodes will be equal to the number of factors considered. If the node i has some connection with the node j , an arrow is directed from i towards j . if node j has some connection with node i i.e they have an interrelationship, an arrow is directed from j to i . According to interdependencies of these factors, the directed edges are shown (b/w B_1, B_2, B_3). The digraph is formed as shown and this will help the decision makers and experts to see the analysis of VMI implementation and the interrelationship they have. If they increase beyond a certain limit, complexity of representation is solved by use of matrix form.



The matrix representation: A matrix is easy and informative way of representing a digraph for further computer calculation. The matrix representation of benefit calculated factors in VMI is represented in form of binary matrix b_{ij}

$$B^* = \begin{matrix} & B_1 & B_2 & B_3 \\ \begin{matrix} B_1 \\ B_2 \\ B_3 \end{matrix} & \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \end{matrix}$$

B_1, B_2, B_3 represented VMI effects on three category of factors and b_{ij} represents interdependencies between i and j .

Deciding the Inheritance of factors

| Measure of factor | Value Assigned |
|--------------------------|----------------|
| Extremely insignificant | 1 |
| Very insignificant | 2 |
| Moderately insignificant | 3 |
| Slightly insignificant | 4 |
| Medium value | 5 |
| Slightly significant | 6 |
| Moderately significant | 7 |
| Very significant | 8 |
| Extremely significant | 9 |

Table II [1,2]

Interdependence of factors in VMI

| Qualitative Measure of factor | Value Assigned |
|-------------------------------|----------------|
| Very low | 1 |
| Low | 2 |
| Medium level | 3 |
| High | 4 |
| Very high | 5 |

Quantification of the benefits of applying VMI on Industry using graph theory

$$B^* = \begin{matrix} & B_1 & B_2 & B_3 \\ \begin{matrix} B_1 \\ B_2 \\ B_3 \end{matrix} & \begin{bmatrix} 7 & 4 & 2 \\ 1 & 8 & 2 \\ 2 & 4 & 9 \end{bmatrix} \end{matrix}$$

Permanent representation: Using the distinct representation of diagram and matrix, permanent function of productivity matrix is calculated B^* , the permanent function is a standard matrix function, used in combinatorial mathematics.

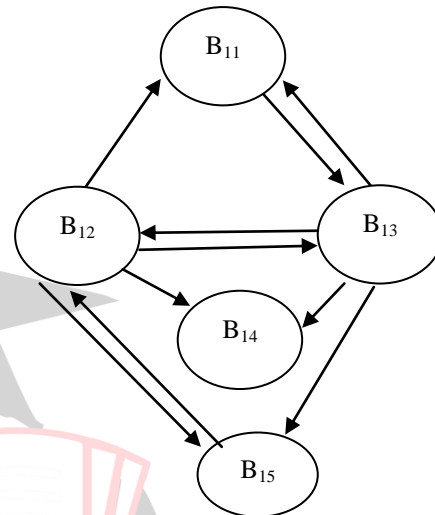
A quantitative value of benefits obtained on applying VMI is calculated using this permanent function. The equation obtained contains 31 terms and these are arranged in $n+1$ groupings,

Where n is the number of factors.

Here $n = 3$.

$$\text{'BOV'} = \text{Per } B = B_1 B_2 B_3 + (b_{12} b_{21}) B_3 + (b_{13} b_{31}) B_2 + (b_{23} b_{32}) B_1 + (b_{12} b_{23} b_{31} + b_{13} b_{32} b_{21}) B_3$$

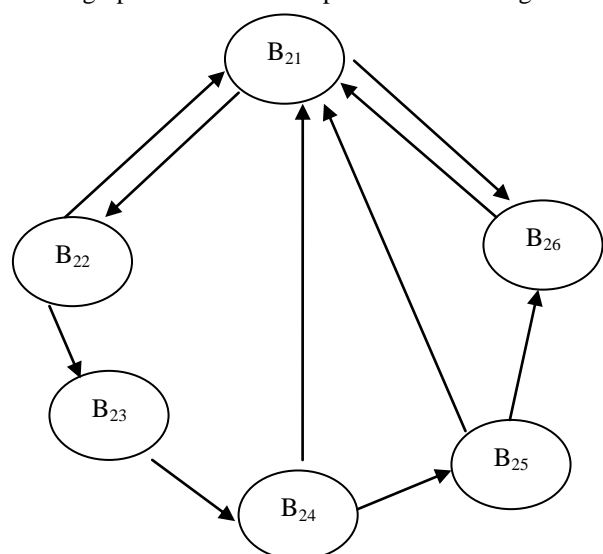
Formation of digraph of decisive factors: The first classification of factors is represented in the form of digraph as:



The corresponding matrix formed is given as:

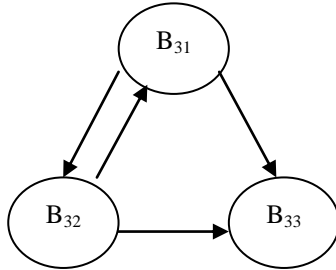
$$\begin{matrix} & B_{11} & B_{12} & B_{13} & B_{14} & B_{15} \\ \begin{matrix} B_{11} \\ B_{12} \\ B_{13} \\ B_{14} \\ B_{15} \end{matrix} & \begin{bmatrix} 8 & 3 & 3 & 5 & 2 \\ 4 & 8 & 3 & 4 & 3 \\ 4 & 4 & 7 & 4 & 2 \\ 2 & 4 & 3 & 7 & 3 \\ 3 & 4 & 2 & 3 & 6 \end{bmatrix} \end{matrix} = B_1^*$$

The digraph formed for the operative factors is given as:



$$\begin{matrix} B_{21} & B_{22} & B_{23} & B_{24} & B_{25} & B_{26} \\ B_{21} & 8 & 4 & 2 & 3 & 4 & 4 \\ B_{22} & 3 & 7 & 1 & 1 & 3 & 3 \\ B_{23} & 1 & 2 & 4 & 1 & 1 & 2 \\ B_{24} & 1 & 2 & 1 & 3 & 1 & 3 \\ B_{25} & 4 & 4 & 2 & 2 & 6 & 3 \\ B_{26} & 4 & 4 & 3 & 2 & 4 & 8 \end{matrix} = B_2^*$$

For budgeting factors the digraph is given as



The matrix that corresponds to this is given by:

$$B_3^* = \begin{matrix} & B_{31} & B_{32} & B_{33} \\ B_{31} & 7 & 2 & 4 \\ B_{32} & 3 & 9 & 5 \\ B_{33} & 4 & 4 & 8 \end{matrix}$$

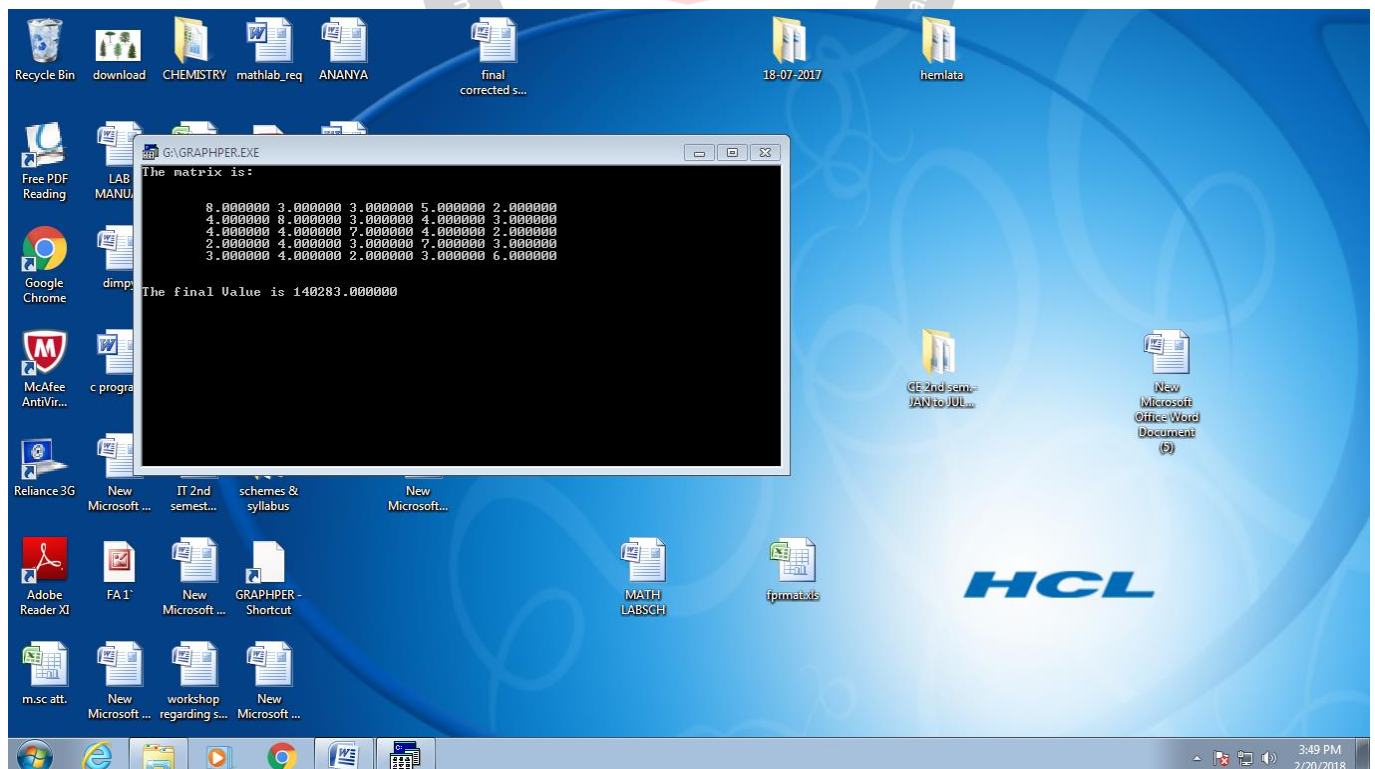
The application: In this application phase of research, researchers tried to access benefits of VMI on small scale industry using VMI for resolving inventory issues. We followed the following steps:

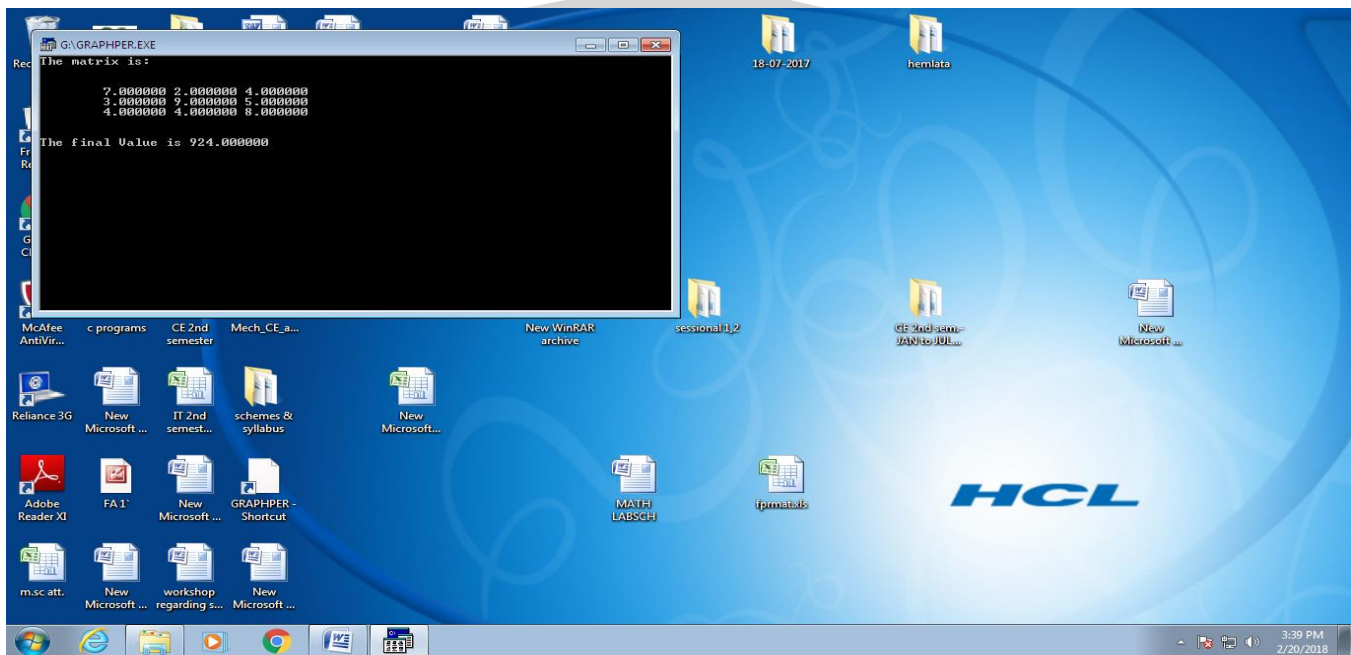
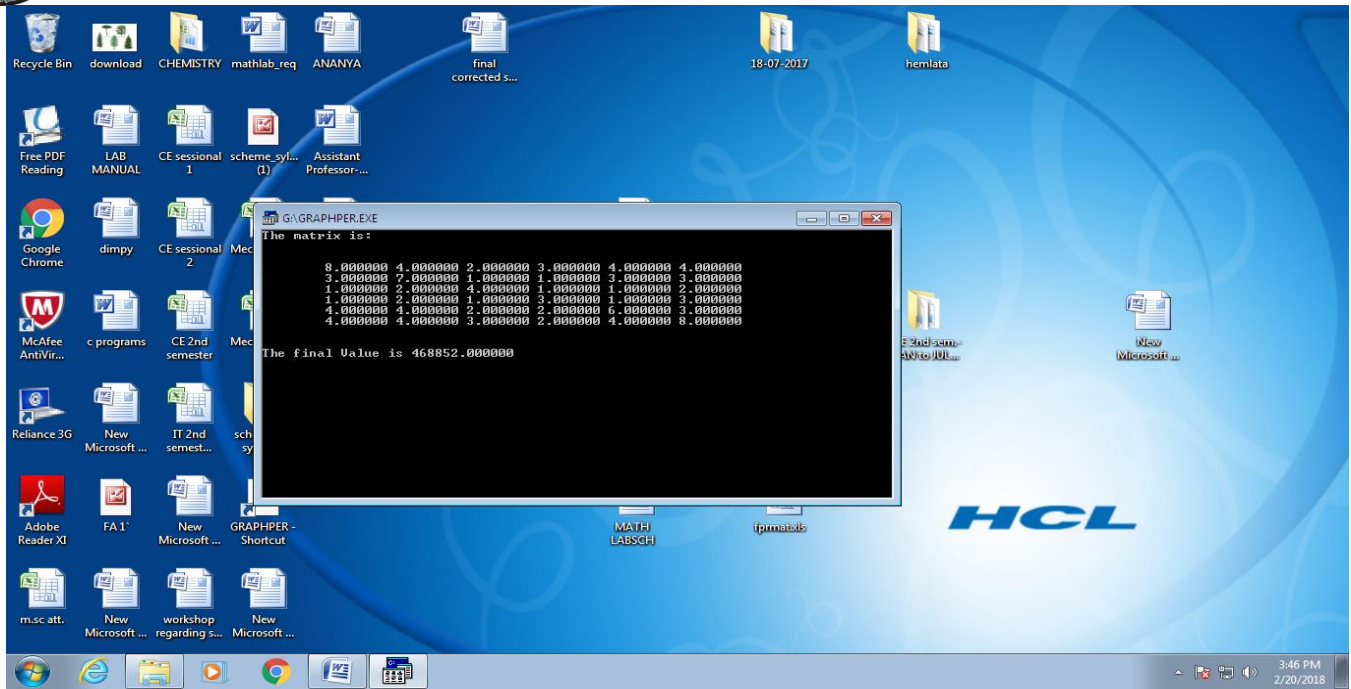
- 1) We identified the major factors and used the table I for values.
- 2) The various sub-factors listed under the major factor were assigned values from table I.
- 3) Directed graph is developed showing the linkage b/w them.
- 4) The numerical inheritance values are assigned and the interdependent values are also assigned.(using the tables II and III)
- 5) The matrix and digraph are formed for all three categories of factors.
- 6) The values are calculated for B_1^* , B_2^* , B_3^* and B^* using GRAPHER tool.
- 7) These values are then compared with the hypothetical maxima that can be obtained in each category and analyzed for further scope of improvement in each of the factors.

Results calculated using GRAPHER:

‘GRAPHER’ is a tool specifically designed to calculate the permanent function of interdependent factors. This tool is used to calculate result from the matrix obtained using digraph. The numeric value obtained in our case shows the benefits derived by the industry from that particular category of factors.

Value obtained for B_1^* , B_2^* , B_3^* and B^* respectively are:





The values resulted are not sufficient alone, so we need some yardstick as a reference so as to give any direction about the further possibilities of improvement in the existing weightage that has been assigned to the benefits. Therefore, we considered some hypothetical maximum values of these interdependent factors. These hypothetical maximum values are assigned after discussions and feedback of researchers in this field. As these values play a vital role, genuine assessment of maximum possible value is done and value assigned to each interdependent variable.

The final result obtained for attained and maximum values (using Grapher) is compared in the following table:

| Permanent function | Attained value | Maximum value |
|--------------------|----------------|---------------|
| B* | 652 | 897 |

| | | |
|---------|--------|---------|
| B_1^* | 140283 | 250260 |
| B_2^* | 468852 | 1768857 |
| B_3^* | 924 | 1195 |

Table IV

| Permanent function | Scope of improvement |
|--------------------|----------------------|
| B* | 27.31% |
| B_1^* | 43.94% |
| B_2^* | 73.49% |
| B_3^* | 22.67% |

Table V

Table IV gives a quantitative view of gaps in achieving the benefits, attained values are the values that are feasible for

the manufacturer to achieve. The values assigned to all interdependent factors are discussed with the manufacturer and experts. Maximum values are the hypothetical maximum values which are decided after discussions with the researchers and supply chain managers who are actually involved in these processes. These are the best possible interdependent values. The comparison between the two values gives us the scope for further improvement in each category.

Table V shows that the global benefits out of Vendor Managed inventory can be improved significantly by 27.31%, whereas individually the decisive factors show an improvement level of 43.94%, the operative factors that are in fact responsible for carrying out the whole management process bring up to growth of around 73.49%, which means substantial scope of improvement in whole process. The third category of factors is the budgeting factors which shows that the financial benefits can be improved further by about 22.67%. These resulted values give us the exact quantitative data required for further improvement of process.

VI. CONCLUSION

This article is regarding the quantification of benefits of applying Vendor Managed Inventory on an auto parts manufacturer in North India. The extensive classification of benefits and the factors that are convoluted are done in three groups. The aftermaths so obtained gives us a quick assessment of the benefits that are obtained by the specific industry and using the hypothetical maxima, the supplementary scope of improvement in each classification of factors is also analyzed. Thus, the global scope for improving the Benefits of VMI, "BOV" value is about 27% which means with slight change in the interdependencies, the maximum values can be achieved. The maximum scope of improvement lies in the operative factors which principally includes a better management of the entire process. So more is the improvement in management and forecasting market trends implies a better profit and more benefits of Vendor Managed Inventory. This entire study is very advantageous as this analysis will be very beneficial for those manufacturers who are preparing themselves for implementing the process of Vendor Managed Inventory.

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