Analysis of Value Stream Mapping and its Benefits

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Abstract—The role of value stream mapping needs to be identified and recognised as an important research area. The literature has identified major fivebenefits of value stream mapping (VSMBs). The data obtained from industry response has statistically analysed by statistical software SPSS version 20.0. The primary goal of this research work is to rank the VSM benefits (VSMBs) from qualitative to quantitative and find out the descriptive analysisof all VSMBs, and further analyze the VSM benefits through exploratory factor analysis. To achieve the above objective, the research theme has divided into three segments. (1) To identify the benefits of value stream mapping and rank them by using statistical mean, (2) To establish the – inter-correlation matrixamong benefits using Pearson Correlation, (3) to develop aexploratory model based on Principal Component Analysis.Findings of statistical analysis are in line with literature review and reveal that significant benefits gained by Indian industry have been included the improvement of manufacturing productivity,reduction of lead time, and reduction of work in process inventory.In nutshell, to develop structural models in Indian perspective, analysing the interaction between the benefitsof value stream mapping in enterprises, is an effort towards promoting lean philosophy.

Keywords—Exploratory Factor Analysis,Statistical Descriptive Analysis, Value Stream Mapping (VSM)

I. INTRODUCTION

Value stream mapping is an important lean tool. It can be a survival strategy of Indian industry during present economic crises condition due to Covid-19 pandemic. Value stream mapping (VSM) is a lean tool that has represented production flows, mapping value stream of a product or family of products, and identified some kind of wastes in production line process[1-3].There is a need to highlighting some benefits of this lean tool. Due to unawareness, most of Indian industry could not get benefitted by successfully implementing this tool. Therefore an action plan is needed to identify and statically analyse the benefits of VSM.

In the view of action plan the objectives of the present research are breaking down into four segments:

- To identify the VSM benefits and rank them.
- To establish inter-correlation matrix among theVSM benefits.
- To conduct astatistical descriptive analysis.
- To develop a model using exploratory factor analysis.

II. LITURATURE REVIEW

A. VSM Review

Many authors reported some benefits of Value stream mapping in their case study. Authors[4]considered a case study that has reported VSM benefits as reduction in WIP inventory by 80.09%, finished goods inventory reduction by 50%, product lead time by 82.12%, station cycle time by 3.75%, set-up time by 6.75% and workforce required by 16.66%.However, Authors[5] reported VSM benefits by a case study of an Indian manufacturing industry that shown 92.58%, reduction in lead time, 2.17% reduction in processing time, 97.1% reduction in WIP and 26.08% reduction in workforce requirement.

Further, authors[3] highlighted a case study of a small manufacturing firm and claimed 33.18% reduction in cycle time, 81.5% reduction in set-up time, 81.4% reduction in lead time and 1.41% reduction in value-added time by successful VSM implementation.

A case study by authors[6]revealed that the value addition percentage (%VA) of the coil shop has increased by 7% and productivity improvement of 76 % after the VSM implementation. Authors [7] illustrates the application procedure of VSM in the manufacturing firm to develop current and target states map.

Reference[8] reported benefits of VSM as 24.56 percentage reduction in production lead times, 69.41 percentage reduction in cycle time, and 18.26 percentage reduction in work in-process inventory for the replacement ball product. Also, Weldon ball end product reported 25.88 percentage reductions in lead time was noted,51.87 percentage reduction in cycle time, and 21.51 percentage reduction in work in-process inventory.

However, Indian industries are still required to gain the full benefits of lean manufacturing. Authors[2] suggested a model in which value stream mapping is positively correlated with manufacturing performance.Authors[1]developed a simulation model that contrast the ‘‘before’’ and ‘‘after’’ scenarios in detail, to illustrate VSM benefits such as lower work-in-process inventory and reduced production lead-time.

B. Identification of Major Benefits of VSM

Theliterature review has been classified into four study segments as case study (C1), conceptual study (C2), empirical or modeling based study (C3) and survey base study (C4).Thefive major benefits of value stream mapping identified from literature review that reflects the performance of Indian industries.

Table 1 : Review of VSM benefits in Indian context

S. No.	Authors (year)	*Review Categories	Benefits with application				
			B1	B2	B3	B4	B5
1	[1]	C2,C3		×		×	
2	[9]	C4				×	
3	[10]	C1,C3				×	
4	[11]	C3,C4				×	×

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5	[12]	C4	×	×	×	×		
6	[13]	C2		×				
7	[5]	C2	×	×	×	×	×	

Source: researcher literature review

Table 1 present the benefits after effective implementation of the lean practices. The major VSM benefits are reduction of manpower (B1), reduction of lead time (B2), improvement of manufacturing productivity (B3), reduction of work in process inventory (B4), shop floor space utilization (B5).

III. RESEARCH METHODOLOGY

The present study has progressed by setting research objectives that lead to review of the literature. The methodology includes a questionnaire-based survey approach to achieve the objectives of this research.

A. Questionnaire-Based Survey

Research in value stream mapping, which explicitly employs either a quantitative approach or a qualitative approach, can present fundamental challenges in understanding the results achieved. This challenge can be met throughout by integrating expert response and industry response in a mixed method research approach, and the researchers [14-18] were able to comprehend this possible prejudice of the collected data better, to answer the research question.

For this reason, the studies of mixed methods, are acting as a functional paradigm. Questionnaire based survey is a kind of mixed method.The survey method enabled to gather a more massive amount of data and information from target respondents within a short period. This method followed by the analytical, descriptive approach, which was genuinely suitable for describing the mean value, standard deviation, and exploratory factor analysis of VSM practices.

The survey questionnaire was designed with the help of literature review and past experience of the researchers. Participants were asked to rate the importance of VSM benefits on a five-point Likert scale. The Likert scale ranged from 1= not important to 5= extreme important[19]. Apart this, 0 included in questionnaire and indicated that given variables/parameter is not applicable in the participants work area. Researcher tried hard to designed questionnaire simple to read and easy to understand.

B. Data Analysis

This section examines the characteristics of the data received from respondents and to present some broad assessment of the representative nature of the final data sample. After entering the data, variable names are registered, and instructions are coded. On the bottom left of the data editor screen, two tabs labeled Data View and Variable View are appear.

By clicking on variable view, it will produce the variable view window, and then the variables information is modified. In this view, each row provides information for each variable. In order to analyze the data the excel sheet was then exported to SPSS 20.0 software. Further, the data was analyzed in two segments such as descriptive data analysis, and exploratory factor analysis (EFA) which are depicted in next section.

C. Descriptive Data Analysis

Theanalyses of raw quantitative data are very essential part of any survey based statistical methodology. The descriptive analysis provides estimates of the characteristics of the data like central tendency measures such as mean, median, and mode; variability or dispersion measures like standard deviation, range of scores, and some information on the distribution of scores for skewness and kurtosis[20]. For good distribution, the value of skewness between -2 to + 2and the value of kurtosis between -3 to + 3 are considered acceptable to prove normal univariate distribution[21].

D. Exploratory Factor Analysis

Factor analysis is an interdependence technique whose primary purpose is to define the underlying structure among the variables in the analysis. Factor analysis is used to establish validity by many researchers[22]. Exploratory factor analysis (EFA) explores the data and provides the researcher with information about how many factors are needed to best represent the data. The collected data were analyzed using Factor Analysis first to group the similar dimensions and have a smaller construct for finding out the representative impact of the factors.

Steps for a Factor Analysis are as follows [23];

- Selecting and measuring a group of variables
- Preparing the correlation matrix
- Determining the number of components or factors to be considered
- Extracting a set of components or factors from the correlation matrix
- Rotating the components or factors to increase interpretability
- Interpreting the results

IV. RESULTS AND DISCUSSIONS

After getting response, data have been further tested with the help of the statistical software package SPSS version 20. Reliability of the scales has been checked through Cronbach's alpha (α), and all the constructs were found to be reliable, as all alpha coefficients have exceeded the minimum accepted value of 0.7[24].

Analyses associated to cover the purpose of the study are as follows:

- Descriptive Analysisof VSM Benefits
- Exploratory Factor Analysisof VSM Benefits

A. Descriptive Analysis of VSM Benefits

VSM benefits are listed in Table 2 as a part of VSM practice. The mean importance values ranged from 1.23 to 2.21. The mean value ranged was low because of limited industries responded which was VSM implemented in the Indian context. Reduction of work in process inventory (Mean 2.21) is the most important benefits gain by Indian Industries.

Further, improvement of manufacturing productivity, and reduction of lead time (Mean 2.17, and 2.16) play an intermediate role. While shop floor space utilization, and reduction of manpower (Mean 1.57 and 1.23) are the least important benefits achieved by respondent industries in practice. Skewness and kurtosis values are found in range that reflects good distribution by respondents.

Significant VSM Benefits: Index for VSM benefits was observed as 1.87 based on the level of significance. Significant benefits gained by Indian industry have been included the reduction of lead time, reduction of work in process inventory, and improvement of manufacturing productivity.

TABLE 2: RESULT SUMMARY OF THE DESCRIPTIVE STATISTICS

S. no.	VSM Benefits	Mean	Skewness	Kurtosis	Rank
1	Reduction of manpower	1.23	0.97	0.51	5
2	Reduction of lead time	2.16	0.12	-1.46	3
3	Improvement of manufacturing productivity	2.17	0.16	-1.47	2
4	Reduction of work in process inventory	2.21	0.14	-1.51	1
5	Shop floor space utilization	1.57	0.78	-0.17	4

It is suggested that top management and decision maker can take benefits from this study and put more emphasis on the significant VSM practices to enhance the Indian industries performance. In the above analysis, no data was found as missing. Hence, the screened data set now can be further used for the subsequent analysis in the present study.

B. Exploratory Factor Analysisof VSM Benefits

The exploratory factor analysis (EFA) result verifies the absoluteness of the scales toward a specific construct. Factor analysis, according to [25], aims at orderly simplification of a large number of inter-correlated measures to a few representative constructs or factors.

The correlation matrix (Table 3) presents the coefficient of correlation between VSM benefits and inter-correlations, that are found significant i.e. greater than 0.33. The positive determinant value, like .019, signifies that there is minimal overlapping between VSMBs with high correlation.All the VSM benefits correlate significantly with each other at the 0.01 level (2-tailed).

TABLE 3: INTER-CORRELATION MATRIX AMONG VSM BENEFITS

VSMBs	Description	1	2	3	4	5
1	Reduction of manpower	1	-	-	-	-
2	Reduction of lead time	.605**	1	-	-	-
3	Improvement of manufacturing productivity	.586**	.831**	1	-	-
4	Reduction of work in process inventory	.599**	.868**	.830**	1	-
5	Shop floor space utilization	.621**	.580**	.619**	.648**	1

Notes: *Pearson Correlation: N=151; Determinant = .019;*
***. Correlation is significant at the 0.01 level (2-tailed).*

TABLE 4: KAISER-MEYER-OLKIN (KMO) AND BARTLETT'S TEST

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.854
Bartlett's Test of Sphericity	Approx. Chi-Square	586.245
	df	10
	Sig.	.000

The KMO measure of sampling adequacy as given in table 4 is 0.854, which is close to 1, indicated a qualified degree of common variance. Bartlett's Test of Sphericity yielded an approx. chi-square value of 587 at a confidence interval of 99% (significance < < .001), indicating that the sample inter-correlation matrix did not come from a population in which the inter-correlation matrix is an identity matrix.

The Table 5 shows the communality estimates before and after factor extraction. This presents the communality of each variable (i.e., the proportion of variance in each variable accounted for by the common factors). In using the principal components method of factor extraction, it is possible to compute as many factors as there are variables.

TABLE 5: COMMUNALITY ESTIMATES BEFORE AND AFTER FACTOR EXTRACTION

VSMBs Description	Initial	Extraction
1. Reduction of manpower	1.000	.606
2. Reduction of lead time	1.000	.827
3. Improvement of manufacturing productivity	1.000	.817
4. Reduction of work in process inventory	1.000	.851
5. Shop floor space utilization	1.000	.630

Extraction Method: Principal Component Analysis.

When all factors are included in the solution, all of the variances of each variable are accounted for by the common factors. Thus, the proportion of variance accounted for by the common factors, or the communality of a variable is 1 for all the variables.

The Table 6 presents the number of common factors computed, the Eigen values associated with these factors, the percentage of total variance accounted for by each factor, and the cumulative percentage of total variance accounted for by the factors.

TABLE 6: TOTAL VARIANCE EXPLAINED

Compo-nent	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.731	74.626	74.626	3.731	74.626	74.626
2	.578	11.555	86.181			
3	.385	7.696	93.877			
4	.181	3.620	97.498			
5	.125	2.502	100.000			

Extraction Method: Principal Component Analysis.

Using the criterion of retaining only factors with Eigen values of 1 or greater, one component has been extracted for rotation. Thus, 74.63% of the total variance is found to be explained by these the single factors. Hence, a model with one factor may be adequate to represent the data. Total variance explained indicates how much of the variability in the data has been modeled by the extracted factors. Figure 1indicated the Scree plot of Eigenvalues against the number of factors to extraction. In this figure, one factor is extracted which has more than one eigenvalue.

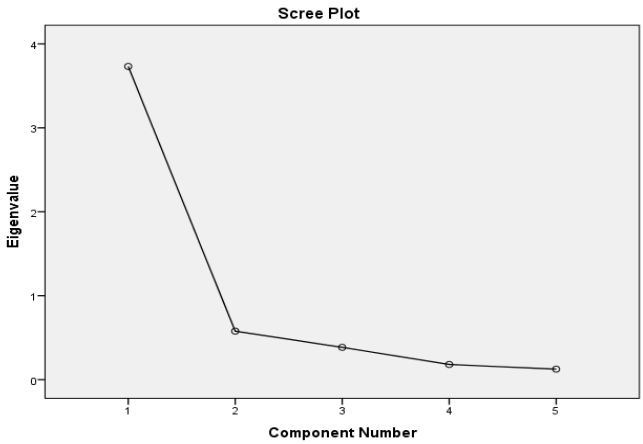

Fig. 1.Scree plot of VSM Benefits

Table 7 presents the component matrix using Principal Component Analysis as extraction method. There is no rotation converged due to 1 factor extracted. Exploratory factor analysis has extracted one factor from the list of 05 VSM benefits with having greater than 0.77 elements loading.

TABLE 7: VSM BENEFITS THAT ENHANCE THE INDUSTRIES PERFORMANCE – COMPONENT MATRIX[A]

VSM Benefits description	Component loading	Factor labels
	Factor 1	
4 Reduction of work in process inventory	.923	VSM Benefits
2 Reduction of lead time	.909	
3 Improvement of manufacturing productivity	.904	
5 Shop floor space utilization	.794	
1 Reduction of manpower	.778	
Cronbach's Alpha value	0.913	

Note: Extraction Method: Principal Component Analysis.
A. 1 components extracted hence the solution cannot be rotated.

Clustering of elements in a factor and their words provides the best clues as the meaning of that factor and also helps in assigning appropriate names to that factor. The component matrix extracted one factor. Therefore, the heading variable is labeled as the factor i.e. 'VSM Benefits'. The results of the reliability test for VSM benefits are also shown in Tables 7. 'VSM Benefits' has Cronbach‟ s alpha (α) 0.913, which is exceeding the minimum value of 0.7. Therefore, the researcher estimates that the constructs of the factor of VSM benefits is internally consistent and reliable. Finally, the Figure 2 shows the Exploratory Factor Analysis model for VSM benefits. Now as a factor represent the five VSM elements. It is noted that all the factor loading are greater than .40 for the 151 response data sample size which reveals a significant role of the VSM benefits model's.

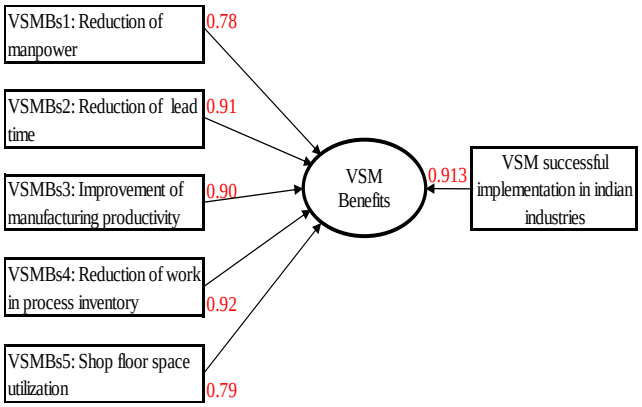

Fig. 2. Value stream mapping benefits- exploratory model

V. CONCLUSIONS

The research findings are translated as conclusions to enable contributions to the existing body of knowledge related to value stream mapping for Indian industries. Value stream mapping is the essential practice of lean manufacturing. In this article, the ranks of five VSM benefits were determined through the statistical test.The statistical test included mean value and exploratory factor analysis.

- Significant construct gained by Indian industry have been included the reduction of lead time, reduction of work in process inventory, improvement of manufacturing productivity, shop floor space utilization and reduction of manpower. All construct are laid on a factor as 'VSM Benefits'.
- The positive covariance between VSM benefits indicates the effective application gain of value stream mapping for Indian industries.
- Pearson correlation analysis was tested and observed that most of the benefits correlate significantly with each other (for a level of 0.05) and value of determinant found positive, which reveals a high correlation. KMO value was found up to the mark.
- Exploratory factor analysis was found the factor loading and their bonding. All VSM benefits have Cronbach's alpha (α) more than .70 that reveals that taken benefits are up to the mark.

This research would motivate industry person as well as researcher towards focusing on value stream mapping.

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