A Longitudinal Study of Maturity of Lean Management in Indian Manufacturing Using Exploratory Factor Analysis and Confirmatory Factor Analysis

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Surveys were conducted between the years 2013 to 2017, in select manufacturing companies, known to practice lean management (LM) in India, called LML (LM Leaders), using the LESAT (Lean Enterprise Self-Assessment Tool) questionnaire, Version 2.0. The results indicate that the status of LM in the LML's has improved by about 8% between the years. 24 key variables, out of the 68 included by LESAT, which drive the progress of LM, and which explain 57% of the total variation, were identified by Exploratory Factor Analysis. A Confirmatory Factor Analysis reveals that the results of the EFA are appropriate.

Keywords: Lean Management (LM), Lean Management Leaders (LML), Lean Enterprise Self-Assessment Tool questionnaire (LESAT questionnaire, developed by a consortium of industries sponsored study at MIT, Boston, USA), Principal Component Analysis (PCA), Exploratory Factor Analysis (EFA), factor loadings, Confirmatory Factor Analysis (CFA)

INTRODUCTION

On September 20, 2018, the Prime Minister of India, Mr. Narendra Modi, declared that the country will aim to become a five trillion USD GDP entity by 2022. From the current level of about 2.7 trillion, it is at a good distance, calling for a growth rate of about 25%, as against the last few years of 7.5% average. This is a serious challenge, and how will the economy respond? He also expressed a hope that manufacturing will contribute 1 trillion. Currently, manufacturing contributes about 22% of the GDP, thus setting itself an asking rate of about 37% CAGR. This is not possible without LM, even if. And this is a crisis.

In view of the steep targets being set by the Indian government to increase the GDP growth rate, it becomes incumbent upon Indian companies to ramp up their LM adoption efforts, as, quantum jumps of the magnitude sought can be achieved only by LM. While many studies have been done in India to study the LM status, all of them have been 'snapshot' studies, i.e., one-time data gathering and analysis. While all of them reveal the quantum jumps, there has not been a systematic effort to identify the factors that affect the LM performance over a period of time. For example, whether leadership commitment, adoption of waste reduction, use of Kaizens, or continuous improvement, snapshot studies cannot give the picture over a time period. This can be done only through the rigour of a longitudinal study. Longitudinal studies can reveal root causes, due to repeated data gathering over long time periods. While LM has been in vogue in India since the 1980's, with the looming steep asking rate, it has become imperative that it becomes the prime engine of the demanded growth.

Not only is the subject of academic interest, it is of commercial and governmental concern. For example, the government has rolled out several programs like Make in India, Skill India, and so on, for which a high growth rate support from industry is a must. Government policy making can benefit from a longitudinal study, to discern areas for support, and areas of strength. From the point of view of an academic, it is of interest to identify further areas of research, to enable faster growth rates. It is also important to develop study instruments which can isolate factors, demonstrate correlations, estimate the variances using bivariate and multivariate analytic tools, pin point areas for improvement by studying the means and standard deviations as well as the co-efficient of variance of component variables. By studying the trend of key variables like strategic planning, closing of the feedback loop for PDCA, cascading initiatives across the organization, the practitioner would also benefit by allocating resources better and pushing for results in key areas.

This author has chosen to study the developments in the adoption of LM by large Indian manufacturing corporates in the last five years to address the above issues. By studying the LM practices in the companies which are known to be LML's (LM Leaders) in the Indian industry, the author proposes to suggest steps to be taken to accelerate the LM implementation speed. To do this, use has been made of tools and techniques like EFA, PCA, t tests, F tests and CFA.

HISTORICAL BACKGROUND

LM is a collection of principles and practices developed as a part of the Toyota Production System (TPS) (Liker, 2014, Hopp and Spearman, 2004, Womack et al. 1990, 1996, Spear and Bowen, 1999, Krafcik, 1988,1989, and Jacquemont, 2014). The scope of coverage of LM is summarized below (table 1).

TABLE 1
SCOPE OF COVERAGE OF LM

Area of application of Lean	Typical practices	Typical benefits
Manufacturing	Lead time reduction	Shorter mfg. cycles
	Set up time reduction (SMED)	Smaller batch sizes
	Single unit flow	Flexible production
	Pull production (or Kanban)	Low inventories
	Takt time	Customer satisfaction
	Heijunka (or levelled production)	As above
	Andon	High quality, consistent
	JIT	Low inventories
	Reduced materials transport	Less damage and waste
	Reduced materials handling	As above
	Autonomation	Relevant automation
Logistics	Milk runs	Faster replenishment
	Short lead time	Smaller lot size
	Smaller shipments	Lower lead times, flexi
	Faster turn around	Speedier despatch
	Use of warehouses	Lower inventory
	Cross docking	Accuracy & lower cost
Procurement	Sensei	Win win
	Strategic sourcing	Long term
	Co-location	High co-ordination
	JIT	Flexibility
	Kanban supplies	Low inventories

IT companies	Scrum Bench	Lead time reduction Flexible allocation
Banking	Value Stream Mapping Process streamlining Process metrics & monitoring Parallel processing	Eliminate waste Improve efficiency Kaizens Shorter lead times
Other services	Waste reduction	Low prices to customers

LM was introduced in Indian industry around 1985 by the TV Sundaram Iyengar & Sons (TVS) group of companies, according to Mr. Anil Sachdev, an expert lean consultant in India, who has been working in this field for the last thirty years. Ever since, Lean has been accepted within various industrial sectors in India, such as, automotive, pharma, steel plants (for example, Prashar, 2014, Chowdary and George, 2011, and Roy and Guin, 1999). In their paper published in 2007, Rachna Shah and Peter Ward (2007) wrote: (quote) the approach now known as lean production has become an integral part of the manufacturing landscape in the United States (U.S.) over the last four decades. Its link with superior performance and its ability to provide competitive advantage is well accepted among academics and practitioners alike (e.g., Krafcik, 1988; Shah and Ward, 2003). Even its critics note that alternatives to lean production have not found widespread acceptance and admit that 'lean production will be the standard manufacturing mode of the 21st century'(unquote). Narasimhan et al., 2006, too, show that companies adopting LM fare better than those not doing so.

Womack and Jones, in their book (1996), made two very important points about LM. One, that LM is a customer centric, customer driven movement where the entire organization tries to work as a whole for a great customer experience. No other movement – like TQM, 5S, JIT etc. – so directly puts the customer at the centre of receiving the value created by the Operations Value Chain (OVC) (see Figure 1 below for the OVC in a typical large manufacturing company)

FIGURE 1
OPERATIONS VALUE CHAIN DIAGRAM IN A MANUFACTURING COMPANY (TYPICAL)

In put (or Inbound)	**In Process**	**Output (or Outbound)**
Vendors and suppliers In bound logistics In transit stocks Inspection Defects handling In bound warehouse Storage at company premises Issue to production	Production Maintenance WIP Inspection Quality Control R & D Engineering & Development Project Management Process control Quality control Packaging Systems certification Environment control CSR TQM Business Excellence PPC Strategy Office of the COO	Finished products In plant stocks Out bound logistics Distributors Wholesalers Retailers Customer returns Reverse logistics CCHP

In fact, to propose the customer as the 'Centre-piece' of a company's work, in the 1950's, as Toyota did, was prescient, envisioning a future where competition would be ubiquitous. Second, no other movement gives rise to the quantum jumps in company performance that LM is capable of. Table 2, from the work of Spear and Bowen (1999), is a typical example.

TABLE 2
THE QUANTUM IMPROVEMENTS POSSIBLE THROUGH IMPLEMENTATION OF LM

Feature	1986	1988	1992	1996	1997
Styles	200	325	670	750	750
Units per day	160	230	360	530	550
Units per person	8	11	13	20	26
Productivity Index	100	138	175	197	208
Finished goods inventory (days)	30	2.5	1.8	1.5	1.5
Number of assembly lines	2	2	3	3	2

Source: Steven Spear and Kent Bowen, 1999

Quantum jumps are large and consistent over time, for many years. More such instances can be found in the book by Womack and Jones (1996). Such quantum jumps in company performance in Indian companies have also been reported by Bopanna Chowdhary and Damien George (2011), Sameh and Tamer (2011), Rajenthirakumar et al (2011), Singh et al (2014), Vinodh et al (2012) and Vinodh et al (2015). Bhim Singh, Garg and Sharma (2010), in their study of a company located in northern India and practicing LM, found that reduction in lead time was 83.14 percent, reduction in processing time was 12.62 percent, reduction in work-in-process inventory was 89.47 percent, and reduction in manpower requirement was 30 percent. The rise in productivity per operator was 42.86 percent.

Sangwan et al (2014), have done a comprehensive literature survey of the papers published in LM between 1988 and 2012. They have classified papers according to the type of study. They have identified sixteen papers from India, on Indian industry, which are longitudinal studies. However, none of the studies have been classified as 'exploratory, longitudinal and cross sectional'. In fact, none of the 209 papers are in this category. Their study confirms a gap in this area, and, our paper addresses this gap, for the reasons stated afore.

De Toni, et al., (1996), recommend that process-oriented management is a prerequisite for LM. This view has been implemented through the ISO 9001 and other certifications, use of TQM tools, and, later, using the Malcolm Baldrige framework. Peter Hasle, et al., (2012), Arnaldo, et al., (2018), David Losonci, et al., (2017), and Guilherme, et al., (2018), emphasize the cultural aspects of the LM transformation. They show that leadership behaviour as well as shop floor behaviour are very important for a successful lean implementation. Gemba, as well as, 5S, are tools that are used in LM to reinforce these behaviours. Donna Samuel, et al., (2015), have shown that, after the publication of the famous book 'The machine that changed the world', LM has evolved as a holistic value system which affects public and private sector companies. Fuentes, et al., (2012), present a comprehensive study of the many factors that are present in an organization that need to be considered while making the transformation to LM. For example, relationships with suppliers, with workmen, involvement of leaders in the company, successful practice of the many LM tools and techniques, are all variously important for a sustained LM implementation. However, the benefits due to LM are unquestionable, in the long run.

METHODOLOGY

Selection of Questionnaire

Researchers use different methods to design questionnaires. Amir Abolhassani et al (2016) revised their questionnaire several times, in consultation with two industry experts and four academics. A pilot study was done to determine the time needed to complete the response, after the survey was conducted. Jasti and

Kodali (2014) tested their questionnaire on 30 participants, and then revised the questions in consultation with academics and industry personnel prior to finalization.

On the other hand, Shah and Ward (2003), used a survey questionnaire already prepared by Penton Media and PriceWatehouseCoopers. In fact, they even used the data supplied by Penton. Such a method has the advantages that the preliminary steps, such as, pilot survey, consultations with academics and industry practitioners before the questions are finalized, have been gone through and the questionnaire is 'survey ready'. Hallam and Keating (2014) used the MIT LAI LESAT survey questionnaire for their work. In the present study, we chose the path adopted by Shah and Ward (2003) and Hallam and Keating (2014).

Sample Size

In our study, we needed to do a longitudinal data gathering, the only way in which we can track the trending of the component variables. Only the trends can establish whether the concerned variable needs to be strengthened or is already being improved. For this purpose, we needed to identify an appropriate instrument. We had determined that we would not go the way of many of the snapshot studies, which is, to select a few companies in one or a few sectors, conduct a survey using a questionnaire, and then use the results to reach conclusions. We felt that the sample size would be too small. The recommended sample size in literature is 10 per question (or variable, as in our case), or a minimum of 300. Several websites give formulae for sample size calculation. Van De Geer, 1993, Kalton, 1983, Hedeker et al., 1999, Schlesselmann, 1973, have also made certain recommendations regarding sample sizes, sample data analysis, and so on, the last two specifically on longitudinal sample sizes. According to the sample size for our study works out to 938, with a confidence interval of + or – 3.2%. As per the sample size of 891 is likely to have an error margin of + or – 3.3%. Similarly, using leads to 896, with the confidence level of 95%, margin of error of + or – 3%. Hence, our sample size of 891 appears to be acceptable.

Choice of Instrument for Responses

The next question is the method to be adopted for gathering the data. Since a longitudinal study is done over a period of time, and since 891 persons will be involved, and the questionnaire could be lengthy, it would involve a lot of time and efforts if personal interviews were to be done. In any case, the data gathered through these interviews would not necessarily be more representative and accurate than the one gathered through a questionnaire. In fact, questionnaires elicit written responses, which allows time to the participants to think through their response. However, it is well known that response rates to written surveys are much lower than oral interviews. This particular issue can be addressed in different ways, and, as long as we can ensure high response rates, the questionnaire is more appropriate. Especially, in a longitudinal study, when the interviews would be conducted over years, it would not be possible to ensure uniformity in raising oral questions in a one-to-one situation. Hence, as already mentioned in 3.1, we decided to use a questionnaire designed to measure LM maturity. Prior to selecting a questionnaire, we examined a number of LM models.

Some of the lean maturity models that we examined include the work by Martichenko Nightingale and Mize, 2002, Nesensohn et al., 2014, and, King County Lean Maturity Model. The optimal choice for our work was Nightingale and Mize's work of LESAT. The LESAT model suits our requirement well. It has been developed through contributions and discussions between over one hundred professional managers on both sides of the Atlantic, and tested with over hundreds of professional managers working in companies. Its usefulness has been proven. The questionnaire is comprehensive, and manageable. The questionnaire and its interpretation and responding are so very well documented that there is no need for any interviewer to be present when the respondent is filling up the answers. The obviation of the need to personally interview people is an advantage, as it makes it possible to get more representative responses, in a shorter time period.

Whereas, the Martichenko questionnaire will be administered only by a consulting agency, and that of King county is highly customised to their requirements – of managing a county in the state of Utah in the USA. The work of Nesensohn et al., is suitable for lean construction work. We found some other models, but all these were rejected because either they were too complicated with too many questions (119 in the case of Sangwa and Sangwan, 2017) or they were customised to suit specific requirements, for example, Mohammad et al., 2015. We looked at the MIT website and found the LAI-LESAT version 2.0. The easy availability of the full version of the survey instrument was also a factor in favour of LESAT. The web-search was done as a part of the development of a blended learning course on 'Lean Management' at a reputed management school in India. Quite apart from the fact that we have chosen to use a method similar to those used in literature, the suitability of the LESAT method (LAI LESAT, 2012; LAI LESAT Facilitators Guide, 2012; LAI LESAT Data Entry File, 2012) for our study was the single biggest factor that worked in its favour.

Data Collection

The questionnaire developed by the MIT LAI team, called 'LESAT', version 2.0, was administered by a team of 5 to 6 MBA post graduate program participants per team, 6 to 7 teams per year, in 6 to 7 companies, as a part of the course work for the course "Lean Enterprise" in the one-year, full time, Post Graduate Program of Management (MBA), in a famous B School, where the author is teaching the course. This course has been adapted from the MIT course on "Lean Enterprise", the details of which are available in the MIT website. Selecting to use the LESAT survey instrument had the advantage of our participants being quite familiar with the objectives and the framework of how the LESAT was developed. This would help them in getting speedy responses. Moreover, the version 2.0 measures LM maturity, appropriate for LML's.

Our MBA participants – about 150 of them over five years - knew personnel in the companies – either former colleagues or former students from our institute – who helped them in getting the responses. Responses were received over emails, from respondents who were sent the survey questionnaire over emails. Every company sent 30 responses, except three. Responses were then studied for completeness, and if found incomplete, the concerned respondents were contacted over phone, to get additional data. All the 891 (n=891) responses were thus complete in all respects and usable. This same methodology has been used by Shahram Taj (2005,2008) and Shahram Taj and Cristian (2011) in their studies of LM in Chinese companies.

Analysis of Responses

In our study, the responses have been treated as 'from a group of LM practitioners in the LML'. The entire set of responses each year – about 175, on an average, per year, over the five years 2013 to 2017, for a total of 891 respondents – has been treated as a monolith of views from an LML community of senior, mid-level and junior managers involved in the practice of LM in the LML's. Hence, the study has not attempted to reach any conclusions about any individual company's or industry sector performance. On the contrary, every year's data is to be treated as the views of respondents who are providing the leadership in driving LM adoption in the LML in India. Hence, each respondent is to be seen as a representative of a community, rather than as a member of a company. This is the same method adopted by Sakakibara et al (1993), Gao Shang and Pheng (2012) and Thanki and Thakkar (2014) in their studies. Bhim Singh (2016) obtained responses from 127 LM professionals from different industries in India and analysed the responses as from a community of LM professionals.

In a study on JIT performance, Sakakibara et al (1993) surveyed 41 plants in the USA, with an average of about 21 persons from each plant. They used the PCA to analyse the responses, without any reference to the companies. Same has been done by Gao Shang and Pheng (2012), who surveyed Chinese construction companies. They received responses from a variety of personnel, like, general managers, technicians, contract manager, regional manager, engineer and used their responses as from a 'group of construction professionals' rather than company representatives.

From the responses that we received, databases of responses were created for each year as well as a consolidated one for the five years. All the databases were subject to reliability (Cronbach Alpha, Spearman Brown coefficient, Guttman Split Half coefficient), sample size adequacy (KMO Index), Bartlett's test of sphericity for testing whether the correlation matrix was an identity matrix (none of the matrices were). Further, PCA, followed by EFA, using Direct Oblimin rotation, to extract orthogonal components, were done on the five-year data (between 2013 and 2017), which established that the components were orthogonal – almost ALL correlations values in the component correlations matrix calculated using the SPSS version 24.0 were well below 0.5 (in fact, they were below 0.272). Test of difference of means using t tests, and checking for unidimensionality by examining the loadings of each variable on the orthogonal factors identified (also see Ziegler and Hagermann, 2015), have also been done, to complete the data analysis.

Many researchers use the Cronbach alpha as an indicator of reliability. However, some authors have shown that the Cronbach alpha may not always give the correct idea of reliability; on many occasions, it may understate the same. (see, for example, Cho and Kim, 2014, Cho, 2015, Graham, 2006). Of the three reason cited by Cho and Kim for errors creeping into the Cronbach alpha calculations, we found that the tau correlation is difficult to judge, to establish that the variables are congeneric, as the loadings vary from 0.4 to 0.6; it is quite possible that the underlying distribution is discrete and not continuous; and, finally, it is not possible to establish that the errors are uncorrelated. Hence, in our case, it is difficult to reach a conclusion regarding the appropriateness of Cronbach alpha, as per the conditions specified by Cho and Kim.

There are other reliability measures available, which can be used in place of alpha (McNeish, 2017). We have used all the three metrics, viz., Cronbach Alpha, Spearman Brown coefficient, Guttman split half coefficient and found that the values are not varying much. For example, for the Cronbach alpha value of 0.954 for the full dataset 2013 to 2017, the other values were, 0.902 for the Spearman Brown coefficient, and 0.954, for the Guttman split half coefficient $\lambda 3$. Also, for the final dataset of 6 factors, the Cronbach alpha value was 0.886, for which the Pearson Brown coefficient was calculated as 0.829 and the Guttman $\lambda 3$ value was 0.886 (all calculations done using SPSS Version 24.0).

The CFA shows strong correlations between the components as well as high component loadings by the 24 variables. These indicate unidimensionality of the variables. Perhaps, most importantly, we are studying LM maturity, and all the variables being measured have been derived from a framework which has been tested out for LM by a large team at MIT, and several papers written on the subject. In such a situation, unidimensionality of the variables is implicit and warranted. Hence, it was decided that Cronbach alpha would be used for reliability measurement.

PCA or EFA or ANOVA

PCA has been used by many researchers in data analysis. Shah and Ward (2003), Atul Agarwal et al (2015), Bhim Singh (2016), Ioannis et al (2014), Khadse et al (2013), Sangwan et al (2014) and Bulent et al (2012) have all used PCA to track the cause effect relationship between LM practices and company performance and/or identifying the factors that can be useful for improving LM, for example, by the 'LM bundles' method adopted by Shah and Ward (2003). However, we have chosen the EFA route, as we found that the components were orthogonal. This choice is in alignment with the recommendations of Widaman, 1993, who has recommended EFA over PCA if: the number of variables loading on factors are high, if the variables are orthogonal and if the objective is to obtain knowledge of the latent constructs or factors. As all these conditions are fulfilled in our study, we chose EFA.

Another group of researchers have used the ANOVA, t tests and other methods of using the difference and levels of means and standard deviations of the survey scores to reach inferences. Thanki and Thakkar (2014), Angel and Manuela (2001), Wagner et al (2014), Avinash Panwar et al (2015), Singh et al (2016), Gao Shang and Pheng (2012) are some of the authors who have used such methodologies. In our study, we have used both these methods, viz., EFA and t – tests. Our research focuses on two aspects of LM in the LML's. One, assess the degree to which LM has been adopted in the Indian industry over the years 2013 to 2017. This is done by using ANOVA type of analysis. Second, develop a set of variables using which one can assess the degree of LM in the LML.

The longitudinal study of the industry has been done for the first time, and the results are in consonance with the economic conditions prevailing in India during this period. The results are far more useful than 'snapshot' studies conducted so far. The results help us to get a view of the consistency or otherwise of LM in LML's. The identification of 24 variables, using the EFA technique, as well as confirmation of these by CFA, have also been achieved.

A LITERATURE SURVEY OF THE METHODOLOGIES USED IN THE PAST TO ASSESS LM IN COMPANIES

Literature is replete with studies on LM. Broadly, researchers have adopted the following methodologies:

- M1 - Use questionnaires to study LM in companies in several sectors of the industry
- M2 - Use questionnaires to study LM in companies in a sector of the industry
- M3 - Use questionnaires to study LM in a specific company, as a case study
- M4 - Use studies in literature and develop a LM framework to measure LM in companies, and then use questionnaires to study either one or many companies
- M5 - Use only selected LM performance indices to study the effect of LM on company performance

Most researchers use questionnaires to obtain perception and actual data regarding various aspects of LM implementation. While the M1 to M5 describe the frameworks used, researchers use several methods for analysis of the results obtained from the questionnaires. These include:

- A1 – Artificial Hierarchy Process (AHP)
- A2 – Graph Theory Approach (GTA)
- A3 – ISM (Integrated Structural Modelling)
- A4 – DEA (Data Envelopment Analysis)
- A5 – Structural Equation Modelling (SEM)
- A6 – Analysis of means and standard deviations using ANOVA
- A7 - Continuous Processing Method (CPM)
- A8 - Comparison of Means of perception of the level of the variable and the perception of the importance of the variable to LM
- A9 – Exploratory/Principal Component/ Varimax rotated factor analysis using KMO, Bartlett and Confirmatory Factor Analysis (Optional)
- A10 – Hypothesis testing
- A11 – Progressive Multiple Regression whether LM has been adopted, are reached)
- A13 – DEMATEL

Some researchers use a combination of the analysis types, A1 to A13, as also methods. Thus, a combination of the chosen methodology and the analysis methodology can give rise to a large number of variations in the results obtained. However, if one were to examine the results reported, there are many similarities. For example, most report significant gains in performance, a need to address many factors that make up LM, and, use of tools and techniques embedded in continuous improvement (kaizen) to make the adoption sustainable. On the other hand, while many agree that top management involvement and guidance is a pre-requisite, very few of the models actually ask questions to check this out. Questions are more in the nature of the adoption of the tools and techniques, as well as the results obtained. For example, almost every questionnaire has two parts – the enablers part, consisting of the LM practices (or, alternatively, tools and techniques), like, JIT, kaizen, TPM, waste reduction, and the outcomes part, like, inventory levels, delivery compliance, manufacturing lead time and cycle times.

In table 3 below is shown the summary of the literature on the methods used in research to assess LM status in companies (the columns are for M1 to M5 and the rows are for A1 to A13, ad seriatim, respectively).

LM is a holistic approach to run the operations of a company. It comprises of two parts – one, enablers and two, outcomes (Shah and Ward, 2003; Fatma et al, 2014; Farhana et al, 2009; Bulent Sezena et al, 2012). The enablers or practices are the various initiatives that are taken up to practice, adopt and implement LM in an organization. Characteristics like continuous improvement, involvement of all team members in an organization, willing and enthusiastic participation by vendors and suppliers, are some of the measures of how well the enablers have been accepted and adopted in an organization (Gusman et al, 2013; Ioannis et al, 2014; Gulshan Chauhan and Singh, 2012). Shah and Ward (2003) compiled a list of 22 LM practices and linked them with performance outcomes. They categorized these enablers into four 'practice bundles' and checked by using the PCA method, that they load into four factors. That the practices loaded into comprehensive bundles, was a key finding of their study. They also established that the enablers and performance parameters are closely locked into a cause – effect relationship. Another key finding was that larger firms are more likely to implement LM than smaller ones. In our survey, we have chosen only large firms for study, as they are considered as LML in the Indian industry. Table 4 shows the details:

TABLE 3
METHODS ADOPTED BY RESEARCHERS IN LITERATURE TO SELECT THE LM FRAMEWORK AND METHOD OF ANALYSIS TO STUDY THE DATA GENERATED BY USING THE FRAMEWORK

Analysis	Several sectors	One sector	Case study	Framework from literature and questionnaire	Selected Company
AHP			Varun Ramesh and Rambabu Kodali (2012), Vinodh, Shivraman and Viswesh (2011)		
GTA				Gopalakrishnan Narayanamurthy and Anand Gurumurthy, (2016)	
ISM		J. R. Jadhav, S. S. Mantha, S. B. Rane (2015)	Vipul Gupta, Padmanav Acharya, Manoj Patwardhan, (2013)		
DEA				Hung-Da Wan and Frank Chen, (2008)	
SEM	Vinod And Dino Joy, (2012)				
ANOVA	Amir Abolhassani, Ky Layfield, Bhaskaran Gopalakrishnan, (2016), Angel and Manuela, (2001), Thanki and Thakkar, (2014), Wagner et al (2014)	Avinash Panwar Rakesh Jain A.P.S. Rathore, (2015),			
CPM			Azharul Karim Kazi Arif-Uz-Zaman, (2013),		
Means	Singh, Ramphool Meena and Avinash Panwar, (2016), Jasti Vamsi Krishna and	Gao Shang and Pheng, (2012)			

	Rambabu Kodali, (2016)				
Factor Analyses	Atul Agarwal, Sudeep Sharma, Venkata Sesha Sai Bharath Mannava (2015), Bhim Singh (2016), Ioannis Belekoukiasa, Jose Arturo Garza-Reyesb and Vikas Kumarc (2014), Khadse , Sarode and Wasu (2013), Majed, Ahmed and Rula (2012), Gusman,Teong and Othman, (2013), Shah and Ward, (2003),(2007), Sakakibara, Flynn and Schroeder (1993), Jasti Vamsi Krishna and Rambabu Kodali, (2014), Jasti Vamsi Krishna and Suresh Kurra (2017),	Sangwan, K.S., Bhamu, J., & Mehta, D, (2014), Suresh Prasad, Dinesh Khanduja and Surrender K. Sharma, (2016)		Bulent, Ibrahim and Gulcin (2012),	
Hyp Testing	Amir Abolhassani, Ky Layfield, Bhaskaran Gopalakrishnan, (2016)				
PMR	Shang Gao and Sui Pheng Low (2013),				
General	Gulshan Chauhan, T.P. Singh, (2012), Bhasin (2012), Krishnan and Parveen (2013), Ghosh (2012)	Farhana Ferdousi, Amir Ahmed (2009), Cory Hallam and Jerome Keating (2014), Yadav, Nepal, Goel and Manahty (2010), Mohapatra and Mohanty (2007), Perera and Perera, (2013),	Yogesh and Prabagaran, (2016)	Sherif and Jantanee (2013)	Bhim Singh, S.K. Sharma, (2009), Bhim Singh, S.K. Garg, S.K. Sharma, Chandandeep Grewal (2010), Fatma Pakdil and Karen Moustafa Leonard (2014)
DEMATEL	Vikram Sharma, Dixit and Qadri (2015)				

TABLE 4
COMPANIES WHO WERE INCLUDED IN THE LINGITUDINAL SURVEY, AND THE NUMBER OF RESPONDENTS, TOTAL NUMBER OF RESPONDENTS, n= 891

Year of survey	Company Name	Industry Generic Name	Latest Stock Price (Rupees per share)	Number of respondents
2013	Daimler	Large Auto	*Not Listed*	30
	VRV Pr. Vessels	Medium Sized	*Not Listed*	30
	Maruti	Large Auto	9,200	18
	M & M Auto Div.	Large Auto	790	30
2014	Apollo Tyres	Large Auto Tyre	295	30
	Ashok Leyland	Large Auto	149	30
	Bosch	Large auto component	19,600	30
	Tata Motors	Large Auto	355	30
	Toyota Kirloskar	Large Auto	*Not Listed*	30
	Varroc Lighting	Large Lighting	*Not Listed*	15
	Ford India	Large Auto	*Not Listed*	30
2015	Hero Moto Corp	Large Two-Wheeler	3730	30
		Online Retailer		
	Flipkart	Large Tractor	*Not Listed*	30
	John Deere	Large Consumables	*Not Listed*	30
		Large Earth Moving		
	3M	Large Auto	20,997	30
	Tata Hitachi	Large Auto	*Not listed*	30
		Large Electric		
	Tata Motors		355	30
	Ashok Leyland		149	30
	Schneider Electric		115	18
2016	Asian Paints	Large Paints	1160	30
	Toshiba	Large Battery	*Not listed*	30
	Mondelez	Large Food & Bev	*Not listed*	30
		Large Auto		
	M & M Auto Div.	Large Engg	790	30
	SKF	Large Auto	1,870	30
	Maruti	Large Soft Drinks	9,200	30
	Bisleri		*Not Listed*	30
2017	Tata Hitachi	Large Earth Moving	*Not listed*	30
		Large EPC		
	Larsen and Toubro	Large Auto	1,355	30
	M & M	Large Manufacturing	790	30
	L & T FMSC D & A		Not listed	30
	Tata Motors			
			355	30

Mahapatra and Mohanty (2015) have found, in their study of 67 companies, consisting of discrete and continuous process industries of various types, that discrete manufacturing companies adopt LM more rigorously than continuous process companies. A similar conclusion has been arrived at by Avinash Panwar et al (2015). The companies surveyed in our sample all belong to the discrete manufacturing industry.

In the literature studied for our work, we identified two main streams of approach, which researchers have adopted. One, using an LM framework, assess the LM status in an industry sector or sectors, or, use some specific LM practices and study the effect of these practices in a selected company (using the case study method) or companies (Methods M1 to M5) using different analytical tools, such as, ANOVA, PCA, EFA, etc. The list of such works is already shown in Table 3. Second, there are many researchers who have picked up one company and assessed the effect of LM practices to study the impact of using those practices on company performance. This list is shown in Table 5.

In our work, we have used the method M1 (Table 3), and analysis methods A6, A8 and A9 (Table 3).

TABLE 5
WORKS OF AUTHORS WHO HAVE STUDIED APPLICATION OF LM IN COMPANIES AND RECORDED THE BENEFITS

Name of company	Methodology	Key results	Reference
Confidential, located in Trinidad and Tobago	VSM, 5 Why's	NVA time has been decreased from 1,170 to 420 minutes, TCT has been reduced from 28 to 10 minutes, Workforce has been reduced from 6 to 3 (50 percent), Reduction in WIP inventory from 6,092 to 864 units, Reduction in shop floor area from 144 to 90 square feet2, Reduction in floor space (38 percent) has been achieved.	Bopanna Chowdary and Damien George, 2011
EZDK, Alexandria, Egypt	Pull production, production levelling, Gemba (work place) visits, waste elimination, creating flow, and problems visibility.	Work in process and cycle time decreased by more than 40%. The variability in cycle time- measured by the monthly standard deviation- decreased by 55%. The production levelling created free spaces in the coil yard which helped in standardization and minimization of the cooling time.	Sameh and Tamer, 2011
Confidential, Mid-Western USA	5 Why's, VSM, root cause analysis, kaizen events	Reduction in processing times, improved quality of products, simplified communications	Joseph C. Chen, Ye Lib and Brett D. Shady, 2010
Donnelly Corporation, USA	JIT, continuous improvement, standardized work, small groups problem solving	Lower inventory, higher inventory turns	Russ Scaffede, 2002

Confidential, Sri Lanka	VSM, one-piece flow, 5S, waste reduction	Higher production and productivity, lower defects rate, better quality	Silva, 2012
Plant of a primary multinational pharma company, Europe	Kanban, CONWIP, continuous flow, improved use of space	Total Pipeline Lead Time: target 6 days, achieved 5 days; Throughput Time: target 3 days, achieved 2 days; WIP reduction: target 30%, achieved 37%; Lay-out redesign (walkthrough reduction): target: 300mts, achieved 284 mts.	Maria Elena Nenni, Luca Giustiniano and Luca Pirolo (2014)
Assembly line paint shop of a construction equipment manufacturing company, India	Process improvement, VSM, equipment redesign, waste reduction, reduction of NVA's	Reduction in WIP - 29%, Cycle time reduction - 29%, 89% improvement in Value Added time, 153% improvement in cycle efficiency, 45% reduction in process lead time	Rajenthirakumar, D., Mohanram, P.V., & Harikarthik, S.G. (2011)
Integrated steel plant in eastern India	JIT	8 to 70 % potential savings in raw materials inventory possible	Roy and Guin (1999)
Auto components supplier, India	VSM	Processing time reduction - 22%, Mfg lead time reduction - 33.7%, Value Added ratio improved by 17.6% and WIP down by 50%	Singh, R., Chopra, A., & Kalra, P (2014)
Cee Yes Metals Reclamations Limited, Tiruchirapally, India, a cam shafts manufacturing company	VSM, 5S, IT interventions	Idle time has been decreased from 19,660 to 19,449 minutes, Total cycle time has been reduced from 539 to 525 minutes, Reduction of work-in-progress inventory from 4,660 to 4,610 units, On time delivery improvement from 70 to 85 percent, Reduction (4 percent) in defects has been achieved, Increase (1.72 percent) in uptime has been realized.	Vinodh, Arvind and Somanaathan, (2010)
Auto components manufacturing company, India	VSM		Vinodh, Selvaraj, Chintha and Vimal, (2015),"

RESULTS AND ANALYSIS

Results are presented in two parts. Part I describes the progress in LM over the five-year period, trying to answer the question: have the LML's respondents indicated a positive progress over these years? Have they indicated that the mean scores of LM adoption in 2017 are significantly greater than those in 2013? If so, in which areas? If not, where are the gaps and deficiencies?

Using the results of part I, part II tries to seek answers to the questions: what are the factors that are responsible for the progress of LM in LML's? What implications can this have on the overall LM adoption in India? For now, and the future?

Analysis of Results: Part 1

The data on respondent scores was first analyzed by using F tests, to check whether the population variances are different. The F tests indicated that the variances are the same. The results are tabulated in table 6 below:

TABLE 6
F TEST TO DETERMINE IF THE POPULATION VARIANCES ARE DIFFERENT FOR THE CURRENT STATE SCORES

Comparison of samples	F statistic	F critical One Tail	Level of significance	Conclusion
Means of all sections - current state responses				
2013 and 2017	0.285081	0.45102	0.05	Variances are same
2013 and 2014	0.244815	0.45102	0.05	Variances are same
2014 and 2015	0.235637	0.45102	0.05	Variances are same
2015 and 2016	0.515501	0.45102	0.05	Variances are different
2016 and 2017	0.532286	0.45102	0.05	Variances are different

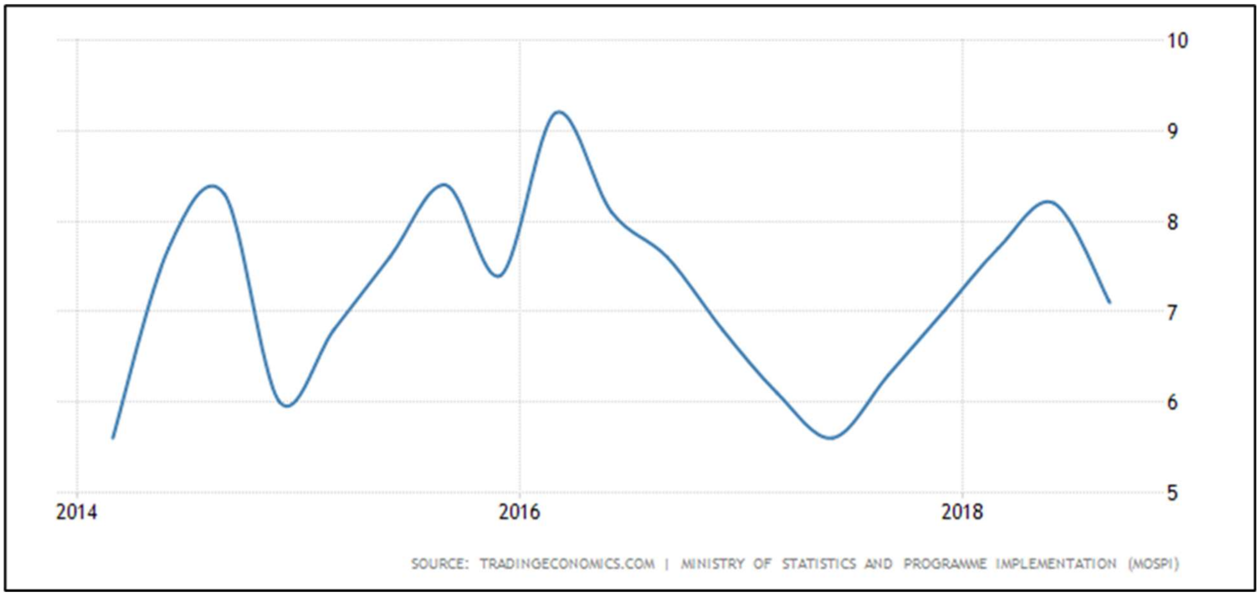
Based on the F tests results, a series of t tests were run to check whether there has been a statistically significant difference between the means of the current state scores (CSS) of the years 2013 to 2017. It can be seen that the average CSS between 2013 and 2017 - 3.0 and 3.23 – are different, but the question is whether this is statistically significant. The data is shown in table 7 below:

TABLE 7
t TEST TO DETERMINE IF THE POPULATION VARIANCES ARE DIFFERENT FOR THE CURRENT STATE SCORES

Comparison of samples	t statistic	t critical Two Tail	Level of significance	Conclusion
Means of all sections - current state responses				
2013 and 2017	3.46780	2.032245	0.05	Means have moved up
2013 and 2014	4.20612	2.028094	0.05	Means have moved down
2014 and 2015	3.91686	2.028094	0.05	Means have moved up
2015 and 2016	7.96133	2.028094	0.05	Means have moved up
2016 and 2017	0.45756	2.028094	0.05	No change in means

The table 7 shows that there is a significant difference between the means of 2013 and 2017, having moved up by almost 8%. This is primarily due to the political situation prevalent in the country. In these years, the country has seen a growth in GDP of between 6 to 9 % (figure 2 below).

FIGURE 2
SHOWING THE GDP GROWTH RATES IN THE YEARS 2014 TO 2018



We compared our results on LM, with those reported in literature. Most researchers, who have used the survey method, have used a Likert scale of 1 to 5 (or, a five-point scale) in their surveys. We give a comparison of the scores reported by some of them in table 8 below:

TABLE 8
ILLUSTRATING THE SCORES OF SURVEYS OF LM ADOPTION IN VARIOUS SECTORS OF INDIAN MANUFACTURING INDUSTRY AND THE CONCLUSIONS REACHED BY THE RESEARCHERS

Reference	Brief description of the work	Average scores for LM enablers	Conclusions
Avinash Panwar Rakesh Jain A.P.S. Rathore, (2015)," Lean implementation in Indian process industries – some empirical evidence ", Journal of Manufacturing Technology Management, Vol. 26, Iss 1 pp. 131 – 160	Surveyed 126 process industry companies in India.	The scores of LM tools varied between 1.27 (takt time) and 4.49 (TPM).	It is observed that the level of implementation of lean manufacturing in Indian process industries is still low
Khadse, Preeti, B, Sarode, AD and Wasu, Renu, (2013), Lean Manufacturing in Indian Industries A Review, International Journal of Latest Trends in Engineering and	Surveyed 31 companies in the Mumbai region in India, using 11 criteria and 51 sub criteria.	The scores varied from 3.23 to 4.42	Though Lean Manufacturing is not a relatively new term for the majority of Indian industries, still the

Technology (IJLTET), Vol. 3, Issue 1, September 2013, pp 175-181			adoption rate of lean practices is average.
Mohapatra, SS and Mohanty, SR, (2007), Lean manufacturing in continuous process industry: an empirical study, Journal of Scientific and Industrial Research, Vol 66, January 2007, pp 19 – 27	Surveyed 29 continuous (CM) and 38 discrete manufacturing (DM) companies in India.	The scores for the 20 LM tools studied varied from 0 (for six sigma) to 4.75 (for takt time)	While CM industries have learnt and adopted some of the LM tools, the DM sector remains largely unaffected by LM.
Singh, MP, Meena, Ramphool and Panwar, Avinash, (2016), A survey of the adoption of lean practices in Indian manufacturing sector, International Journal of Industrial Engineering Research and Development (IJIERD), Volume 7, Issue 2, May-August 2016, pp.52–62	Surveyed 92 companies for LM adoption.	The scores for the 19 LM tools varied from 1.23 (VSM) to 4.56 (5S).	Out of 92 respondents 59 (64%) answered that they are familiar with concept of lean manufacturing. 33 (36%) respondents denied that they are familiar with lean manufacturing. It was found that
Jasti, N.V.K., & Kodali, R. (2016). An empirical study for implementation of lean principles in Indian manufacturing industry. Benchmarking: An International Journal, 23(1), pp 183-207. https://doi.org/10.1108/BIJ-11-2013-0101	Surveyed 180 companies in India. The sample consisted of companies from various sectors of manufacturing, including automobile and textiles.	The scores for the 69 LM tools studied varied from 1.00 (concurrent engineering) to 4.22 (cross functional team working).	The result of the survey clearly shows that most of the respondent organizations have implemented some sort of LM principles in their organization. The study revealed that majority of the organizations was categorized in transition mode (o5 years) of LM principles implementation. The major constraints to implement LM principles were employee resistance and lack of awareness about LM principles among industry professionals.

The scores vary from about 1.0 to 4.5 across industries. Our scores also show the same behaviour. Out of a maximum of 5.0, in our study, the overall averages are between 2.8 to 3.3. However, the most significant part of the result is the increasing trend between 2013 and 2017. There has been an 8% increase in the average CSS, which augurs well for the Indian industry. This is for the first time that, in the Indian industry, a study has been done to estimate the LM adoption over five years, and the results seem to validate previous studies. Second, out study shows that the degree of LM adoption in LML's has gone up, which is a good sign for the economy. We decided to do further analysis, to identify the areas that need to be improved upon, to increase LM adoption. Hence, it was decided to do a PCA/ EFA, to identify and isolate the main LM enablers which drive the adoption of LM in Indian LML's. We also did a CFA to confirm our findings from the EFA.

Analysis of Results: Part 2

The t tests and F tests analysis of each year's data revealed that the difference in the current state scores between the years 2013 and 2017 is statistically significant, with the difference being 8%. However, to identify the variables which have had a long-term impact on the adoption of LM in LMLII, yearly data analysis will not help. LM is a bundle of many variables (Shah and Ward, 2003) and the implementation of LM takes some five to ten years (Womack and Jones, 1996). It was therefore postulated that the longitudinal data for five years, taken together, could be used to identify the variables which have led to the improvement over the five years, instead of analyzing the data for each year separately. By analyzing all the data together, one would get a perspective view of how the average current state scores for each variable has trended, and how, in combination with other variables, influenced the final outcome. Therefore, all EFA/ CFA were run on the consolidated data of the five years between 2013 and 2017. Thus, the longitudinal, study serves two purposes- one, to provide data on year to year changes in the key variables, and, two, giving a consolidated, long term view of the underlying phenomena.

The survey scores of the current state of LM adoption can be analyzed using the PCA/ EFA methodology with the help of the SPSS package 24.0. In our study, we first checked the Cronbach Alpha value of the yearly as well as the consolidated data of the years 2013 to 2017. These are quite high and indicate that the data reliability is assured. The Cronbach Alpha data is shown in table 9 below:

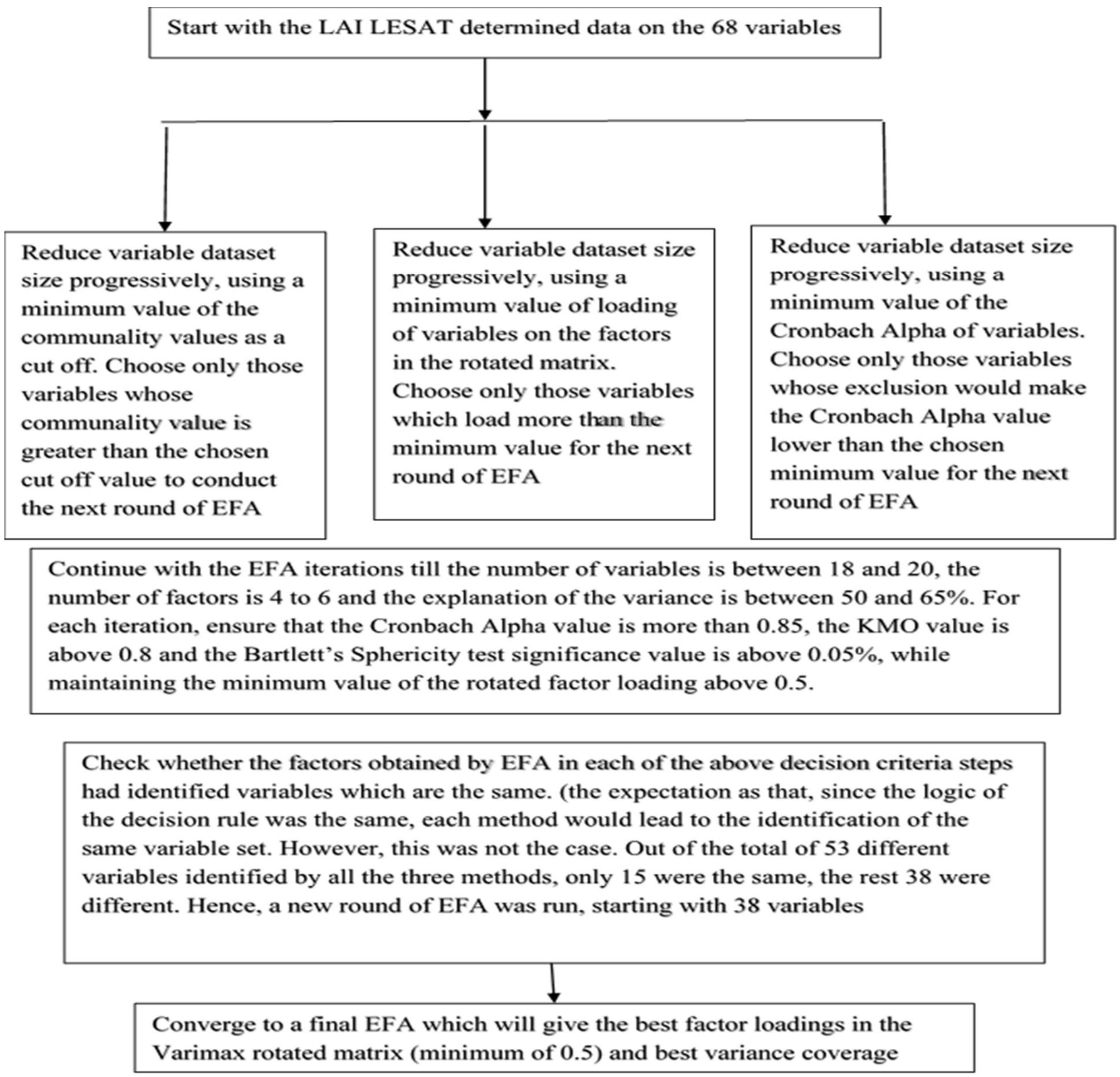
TABLE 9
CRONBACH ALPHA VALUES

Year	Current State	Desired State
2017	0.975	0.965
2016	0.947	0.932
2015	0.970	0.967
2014	0.920	0.973
2013	0.759	0.879

A variety of factor analyses were done, to enable the identification of the most important factors that have the maximum bearing on the LM practices in LML's. EFA is a tool to identify the factors that can explain the variance of phenomena being described by several independent variables. When all these variables, which are measuring various aspects of the same phenomenon, are individually used to get an idea of the status of the phenomenon, the data collection needs are that much higher, the analysis is that much more difficult and calculations are more numerous. Focus is lost. Instead, by using the EFA, if we succeed in identifying a few variables from the universal set, which can describe a large part of the variance, if not in full, then the tracking and monitoring of the variables becomes easier and the phenomenon can be understood better, and we can bring a focus to our improvement efforts.

In the case of Lean, researchers have used several variables. For example, Khadse et al (2013) used 11 criteria and 51 sub criteria as LM practices, Mohapatra and Mohanty (2007) used 20 different variables, Singh et al (2016) used 19 variables, Jasti and Kodali (2016) used 69 variables, all to study the adoption of LM in Indian companies. Each one of them felt the need to identify the factors into which all these variables load into, so that, the factors affecting LM can be understood easily, as well as, the improvement efforts get a proper direction. For example, Shah and Ward (2003) introduced the concept of Lean Bundles, validated by PCA, to compress 22 lean variables into four manageable factors, thereby increasing the understanding about the behavior of the variables, as well as, improving the focus on the efforts needed to improve LM adoption in companies. In our work we have used the PCA, followed by EFA, on data that has been assessed as reliable by the Cronbach Alpha tests, to identify the factors that can be used to compress the 68 variables contained in the 3 sections of the LAI LESAT survey tool, by using a step-wise reduction and optimization, with iterations, methodology. This iterative methodology is shown below (figure 3):

FIGURE 3
ITERATIVE METHODOLOGY OF EFA



At every step, an EFA is done, starting with the number of variables from the previous step. Deletion of variables is done by using a decision rule which is expected to improve the 'explanation of variance' by the factors, reduce the total number of factors and maximize the loading of each variable on the factors in the Varimax rotated factors matrix.

Starting with 68 variables, our effort was to reduce the number of these variables based on specific criteria, to reduce the size of the variable set, using EFA. In doing so, we found that there can be three decision criteria, which can be the three options to achieve our objective:

- Decision criterion 1: Reduce the number of variables, in steps, for EFA using a minimum value of communality as the cut off
- Decision criterion 2: Reduce the number of variables for EFA, in steps, by using a minimum loading value of the rotated component matrix as a cut-off
- Decision criterion 3: Reduce the number of variables for EFA, in steps, by using a minimum value of Cronbach Alpha as a cut-off

The idea in using the three criteria was to find out which one would lead to the best fit, that is, the best factor loadings and the highest variance explanation. By progressively increasing the cut off levels of the communality, the loading value in the rotated components matrix (and, consequently, a reducing Cronbach Alpha), we performed the EFA repeatedly, using the SPSS 24.0 version, for a progressively smaller set of LM variables, and identified only those variables which impact the LM adoption the maximum. In this way we found the best fit for each of the three decision criteria. For each criterion, we used 10,7 and 4 (for a total of 21) iterations to get to the optimal result. We then used the results from this best fit process to again repeat the EFA, to finally isolate the 'most fitting' variables set, which took us another 4 iterations. This set then becomes the one which can be used for analyzing the reasons why the LM adoption level has improved in the Indian LML's.

By using the decision criterion 1 above, we could reduce the variables set from 68 to 18, with the total set of factors going down from 14 to 6, with the Cronbach Alpha also going down from 0.954 to 0.833, still high enough to ensure reliability, after 10 iterations. The final optimum set could explain 61.08 percent of the variation. Similarly, by using the second decision criterion, we isolated a set of 18 variables which loaded into 4 factors, which could explain 51% of the variation, after 7 iterations. By using the third decision criterion, we identified 17 variables, which loaded into 4 factors, and explained 48% of the total variation, after 4 iterations. Obviously, the criterion 1 output was of superior quality. However, before selecting this output, we checked whether the variables isolated by each criterion were the same. This was not the situation, and, out of the total of 53 variables identified by the three criteria, removing 15 which were duplicates, we were left with the rest, 38 unique variables. It was therefore decided to use these 38, which were identified by a process of step-wise reduction and optimization iteratively, for a further round of EFA.

For the final round of step-wise reduction, a minimum communality score was used as a cut off. The communality score was chosen because the decision criterion 1, where this criterion was used, gave the best results, viz, 18 variables, 6 factors and the highest explanation of 61% of the variance, compared with the optimum results obtained from criterion 2 and 3. After 4 iterations we isolated 24 variables which loaded into 6 factors, while explaining 57 % of total variance. Summarized parameters of the EFA are shown in tables 10 and 11 below:

TABLE 10
RESULTS OF THE FINAL EFA RUNS FOR EACH DECISION CRITERION

Analysis set	Decision Criterion 1	Decision Criterion 2	Decision Criterion 3
Number of Variables	18	18	17
Cronbach Alpha	0.833	0.835	0.799
KMO Sampling adequacy	0.841	0.870	0.827
Chi Squared	3678	3670	2714
Degrees of freedom Significance	153 0	153 0	136 0
Factors	6	4	4
% Variation explained	61.08	51.29	48.29

TABLE 11
RESULTS OF THE FINAL ROUND OF RUNS OF PCA USING THE VARIABLES SELECTED BY THE THREE DECISION CRITERIA

Analysis set	I	II	III	IV
Cut off values of Communality	Start of final round of EFA's	0.45	0.45	0.485
Number of Variables	38	30	27	24
Cronbach Alpha	0.915	0.899	0.894	0.886
KMO Sampling adequacy	0.914	0.901	0.902	0.899
Chi Squared	10466	6042	7235	6238
Degrees of freedom	703	435	351	275
Significance	0	0	0	0
Factors	7	6	6	6
% Variation explained	50.41	51.88	54.61	57.02

The final set of 24 variables which loaded well into 6 factors- loadings more than 0.52, with the exception of two variables- is shown in table 12, below:

TABLE 12
FINAL LIST OF VARIABLES AND FACTORS THAT THEY LOADED INTO AFTER THE FINAL ROUND OF EFA'S

Rotated Component Matrix						
	Factors					
	1	2	3	4	5	6
% Explanation of variation (cumulative)	**13**	**22**	**32**	**40**	**49**	**57**
IIC6	0.608					
IID1	0.648					
IID3	0.654					
IIE1	0.705					
IIE6	0.632					
IIIA3	0.443					
IC2		0.566				
IE3		0.760				
IE4		0.696				
IE5		0.672				
IID5			0.731			
IIE5			0.560			
IIB5			0.719			
IIIA5			0.591			
IB1				0.578		
IF1				0.526		
IG2				0.670		
IE6				0.467		
IIA4					0.618	
IIB4					0.664	

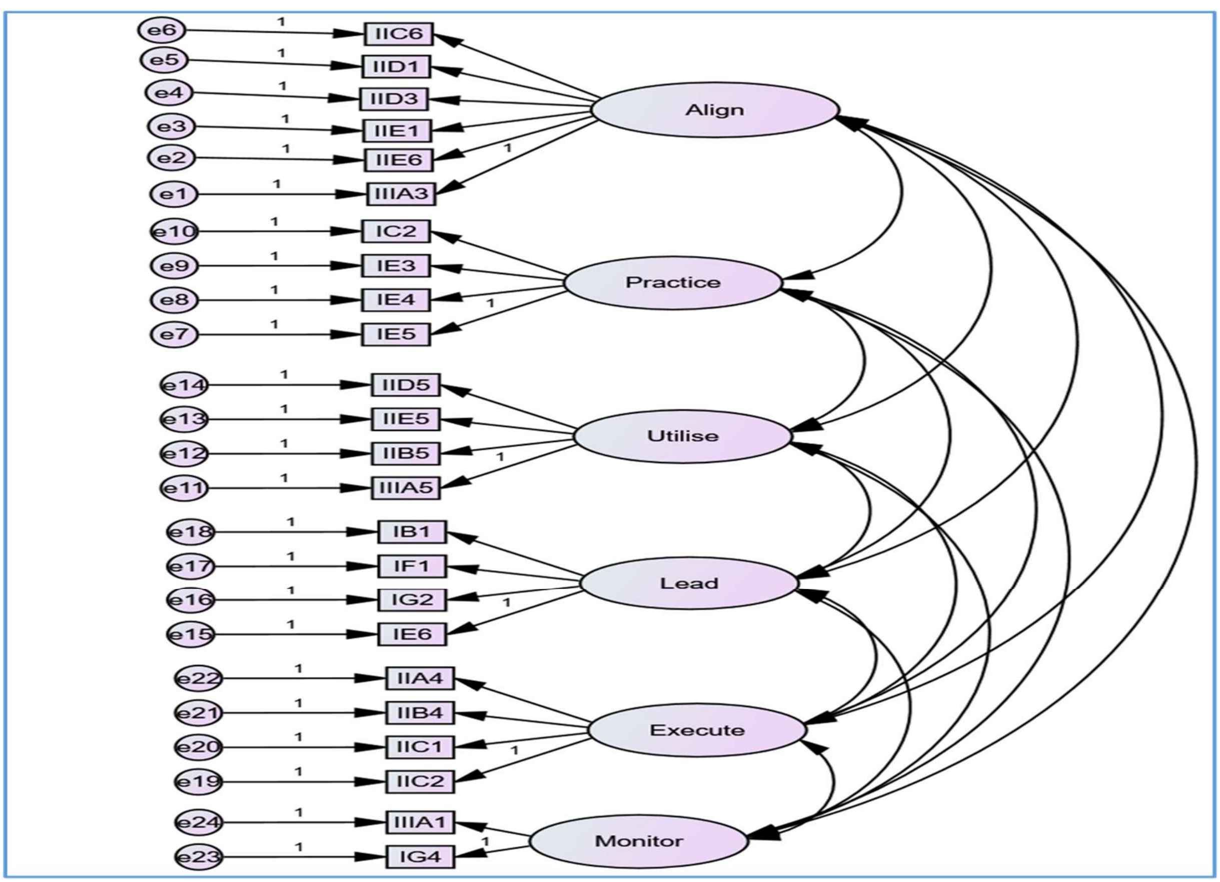
IIC1					0.569	
IIC2					0.636	
IIIA1						0.673
IG4						0.673
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.						
Rotation converged in 10 iterations.						

While all the loadings were above 0.5, two were below 0.5. When compared with the values reported by Shah and Ward (2003), our values are much higher. In our study, we had only two values of 0.443 and 0.467, whereas there were 4 out of 22 values below 0.5 in the other case (Table 4, Op Cit). Shah and Ward (2003), found the 'competitive benchmarking' variable loaded only 0.361 on the TQM factor. In our study, we found that 4 variables loaded over 0.7, 12 beyond 0.6, 6 beyond 0.5 and only 2 below 0.5. We, therefore, believe that the loadings in our study are acceptably high.

Analysis of Results: Part 3: CFA

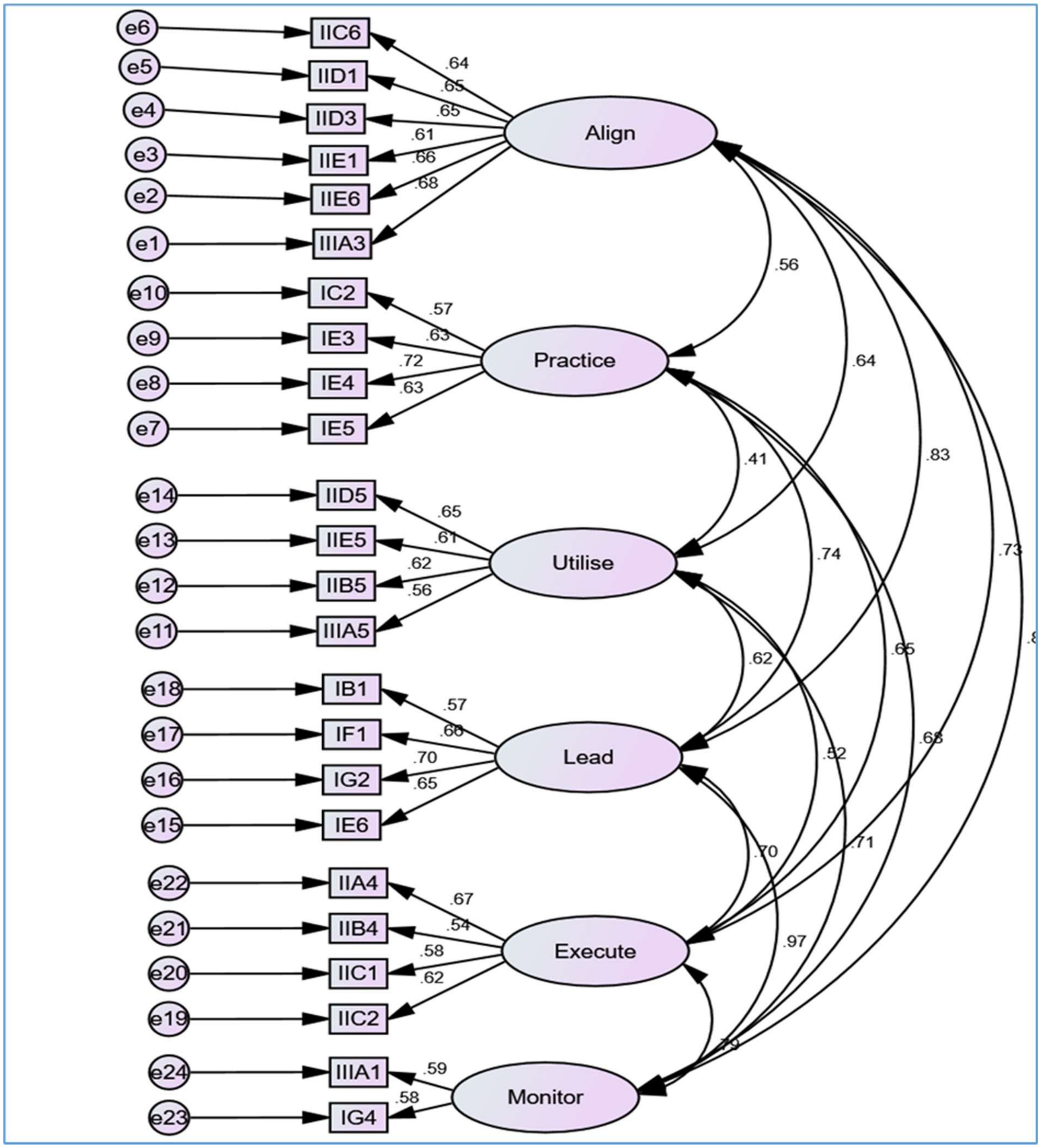
In order to confirm the findings from the EFA, we ran a CFA. 24 variables loaded into 6 factors. The distribution of the variables between the six factors were: 6,4,4,4,4,2. To begin with, we named the six factors as: align, practice, utilize, lead, execute and monitor. These names were chosen based on the nature of the variables loading into the factors, and are shorter versions of the names chosen for the same factors in the final EFA. The arrangement is shown in figure 4.

FIGURE 4
THE SIX FACTORS, 24 VARIABLES AND THE CORRELATIONS FOR THE CFA



The next step was to run the CFA. The standardized output is shown in figure 5.

FIGURE 5
STANDARDISED LOADINGS ON FACTORS OF VARIABLES AFTER RUNNING THE CFA



The factor loadings are quite strong, varying between 0.54 and 0.72, indicating that the CFA confirms the EFA output and conclusions. In order to confirm the strength of the CFA results we looked at the Model fit results from the SPSS, to see whether we needed to make any changes to the model, or if the current model fit is reasonably acceptable. The selected output data is shown in table 13.

MODEL FIT SUMMARY

TABLE 13
OUTPUTS FROM THE CFA

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	63	889.838	237	.000	3.755
Saturated model	300	.000	0		
Independence model	24	1591.053	276	.000	5.765
Zero model	0	10680.000	300	.000	35.600

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.081	.917	.895	.724
Saturated model	.000	1.000		
Independence model	.334	.851	.838	.783
Zero model	.449	.000	.000	.000

BASELINE COMPARISONS

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.441	.349	.518	.422	.504
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

PARSIMONY-ADJUSTED MEASURES

Model	PRATIO	PNFI	PCFI
Default model	.859	.378	.432
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	1.000	.734	.635	.840
Saturated model	.000	.000	.000	.000
Independence model	1.788	1.478	1.341	1.623

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.056	.052	.060	.009
Independence model	.073	.070	.077	.000

The RMSEA value, the RMR, GFI, AGFI, CMIN/DF and the P are all in the acceptable range. The only variable not in the range is CFI, which, at 0.504, is below the preferred 0.8/0.9. Hence, the model fit was considered acceptable. It may be possible to get a better fit model, however, it is proposed to take up that exercise when we get data for the years 2018 and 2019.

DISCUSSIONS

Results indicate that there are 24 variables which load into 6 factors. Based on the nature of the variables, the factors have been named as: resource allocation and alignment, create conditions for employees to practice LM, Utilisation and control of resources to practice LM, Leadership direction and involvement to promote LM, Execution of LM and Monitoring and control of LM. The details are shown in table 14 below:

TABLE 14
FACTORS AND VARIABLES LOADING INTO THEM, AFTER THE FINAL ROUND OF EFA

Sr. No.	Factor Name	Factor description	LESAT sub Category	Factor loadings - rotated weights
1	Resource allocation and alignment	II.C.6. Distribution and sales -	Incorporate Downstream Customer Value into the Enterprise Value Chain	0.608
		II.D.1. Program management -	Actively Engage Upstream Stakeholders to Maximize Value Creation	0.648
		II.D.3. Product development -	Actively Engage Upstream Stakeholders to Maximize Value Creation	0.654
		II.E.1. Program management -	Provide Capability to Monitor and Manage Risk and Performance	0.705
		II.E.6. Distribution and sales -	Provide Capability to Monitor and Manage Risk and Performance	0.632
		III.A.3. Promulgate the learning and sharing organization -	Organizational Enablers	0.443
2	Create conditions for employees to practice LM	I.C.2. Ensure stability and flow within and across the enterprise -	Understand Current Enterprise State	0.566
		I.E.3. Align incentives - Develop Enterprise Structure and Behaviour	Develop Enterprise Structure and Behaviour	0.760
		I.E.4. Empower change agents -	Develop Enterprise Structure and Behaviour	0.696
		I.E.5.Promote relationships based on mutual trust	Develop Enterprise Structure and Behaviour	0.672
3	Utilisation and control of resources to practice LM	II.D.5. Production - Actively Engage Upstream Stakeholders to Maximize Value Creation	Actively Engage Upstream Stakeholders to Maximize Value Creation	0.731
		II.E.5. Production - Provide Capability to Monitor and Manage Risk and Performance	Provide Capability to Monitor and Manage Risk and Performance	0.560

		II.B.5. Production - III.A.5. Integration of environmental protection, health and safety into the business -	Optimize Extended Enterprise Performance Organizational Enablers	0.719 0.591
4	Leadership direction and involvement to promote LM	I.B.1. Cultivate enterprise thinking among leadership -	Engage Enterprise Leadership in Transformation	0.578
		I.F.1. Create enterprise-level transformation plan	Create transformation plan	0.526
		I.G.2. Commit resources for transformation efforts -	Implement and Coordinate Transformation Plan	0.670
		II.E.6. Distribution and sales -	Provide Capability to Monitor and Manage Risk and Performance	0.467
5	Execution of LM	II.A.4. Supply chain management -	Align, Develop, and Leverage Enterprise Capabilities	0.618
		II.B.4. Supply chain management -	Optimize Extended Enterprise Performance	0.664
		II.C.1. Program management -	Incorporate Downstream Customer Value into the Enterprise Value Chain	0.569
		II.C.2. Requirements definition -	Incorporate Downstream Customer Value into the Enterprise Value Chain	0.636
6	Monitoring and control of LM	III.A.1. Enterprise performance measurement system supports enterprise transformation -	Organizational Enablers	0.673
		I.G.4. Track detailed implementation -	Implement and Coordinate Transformation Plan	0.673

Unlike many other works in the literature, our work shows that involvement of and direction from leaders is a clear indicator of LM. Without these two variables, LM cannot be taken to high levels. It is known that LM adoption takes a lot of time, for example, the many case studies cited by Womack and Jones (1996), Fahmi et al (2012). Since LM is an attempt to replicate the Toyota TPS (Liker, 2004), the cultural and people aspects are critical. These factors involve, in many cases, organizational level transformations, which can be attempted only if leaders are involved (also see Kotter, et al., 1996, 2002, 2007 and 2014). The six factors identified cover the entire gamut of LM related activities. The 24 variables are able to explain 57% of the total variance. Thus, the several iterations of EFA have resulted in the identification of the variables and the factors responsible for adoption of LM in the LML's in India. The average scores of the variables in the factors are shown in table 15 below:

TABLE 15
SHOWING THE AVERAGE CS SCORES OF 24 VARIABLES LOADING INTO 6 FACTORS AND THE AVERAGE SCORES FOR THE FACTORS

LESAT sub Category	Average scores CS 2013 - 2017	Average
Incorporate Downstream Customer Value into the Enterprise Value Chain	3.04	3.09
Actively Engage Upstream Stakeholders to Maximize Value Creation	3.12	
Actively Engage Upstream Stakeholders to Maximize Value Creation	3.13	
Provide Capability to Monitor and Manage Risk and Performance	3.12	
Provide Capability to Monitor and Manage Risk and Performance	3.06	
Organizational Enablers	3.04	
Understand Current Enterprise State	3.00	2.94
Develop Enterprise Structure and Behaviour	2.86	
Develop Enterprise Structure and Behaviour	2.89	
Develop Enterprise Structure and Behaviour	2.99	
Actively Engage Upstream Stakeholders to Maximize Value Creation	3.07	3.16
Provide Capability to Monitor and Manage Risk and Performance	3.07	
Optimize Extended Enterprise Performance	3.17	
Organizational Enablers	3.32	
Engage Enterprise Leadership in Transformation	3.00	2.99
Create transformation plan	2.98	
Implement and Coordinate Transformation Plan	2.94	
Provide Capability to Monitor and Manage Risk and Performance	3.05	
Align, Develop, and Leverage Enterprise Capabilities	2.97	2.99
Optimize Extended Enterprise Performance	2.96	
Incorporate Downstream Customer Value into the Enterprise Value Chain	2.91	
Incorporate Downstream Customer Value into the Enterprise Value Chain	3.11	
Organizational Enablers	2.95	2.89
Implement and Coordinate Transformation Plan	2.82	

If we rank the factors based on the average variables loaded CS scores, we will see the table 16 shown below:

TABLE 16
AVERAGE CS SCORES OF FACTORS – USING 891 OBSERVATIONS FOR THE YEARS 2013 TO 2017

Factor	Average variable score over the period 2013 to 2017
Utilisation and control of resources to practice LM	3.16
Resource allocation and alignment	3.09
Leadership direction and involvement to promote LM	2.99
Execution of LM	2.99
Create conditions for employees to practice LM	2.94
Monitoring and control of LM	2.89

While the average scores of two factors – allocation of resources for LM and their utilisation- are above 3.16 and 3.07, all the others are below 2.99. This clearly shows that the adoption of LM in the LML's in India can improve if further progress is made in implementing the four factors well – leadership involvement and engagement, execution of LM, creating conditions for employees to practice LM, monitoring and control of LM. The picture becomes clear – while the leadership has allocated resources and these resources are being utilised, the lack of continuity in the efforts to provide a direction to the utilisation, monitoring the same and doing CAPA (Corrective and Preventive Action) as per ISO systems like ISO 9000, ISO 14000 etc., could improve, leading to further conservation of resources. Evidently, merely providing resources may not result in their high utilisation, if the employees who are to use these, are not motivated enough. Thus, based on the iterative EFA analysis, confirmed by the CFA, which showed quite high correlations between the six factors, indicating that all the factors are contributing singly and severally towards the latent construct of LM Maturity, our conclusion is that improvement in leadership and employee morale will lead to overall high average scores for all the 24 variables. And out of the 68 variables, if these 24 are driven well, the overall adoption of LM in the Indian LML's will surely improve further.

CONCLUSIONS AND FURTHER WORK

The LAI LESAT surveys over five years – 2013 to 2017 – have provided data on the LM adoption in selected LML's in India. By analyzing the scores of the 68 CS variables and comparing them with the other studies in literature, especially those which have been done in Indian companies, it has been shown that these scores do not help us to pinpoint the reasons why the LM adoption is low. It was therefore decided to do EFA. In doing so, it was decided that we should adopt a 3-step process of iteratively using EFA, to arrive at the most optimal set of variables which load well in the Varimax rotated matrix, as well as provide an acceptable level of variance explanation. The three steps are those which are equally likely to yield the optimal results. After the optimal solutions were found, these were examined to check whether they all contain only the same set of variables. It was found that this was not the case, but a set of 38 variables cover all the variables identified in the three optimal solutions. Using this set, further EFA analysis was done, iteratively. The optimal result was obtained after 4 iterations, leading to 24 variables, 6 factors and a 57% explanation of the total variance, Analysis of the results shows that, one, the adoption of LM in LML's has improved by 8% over the years 2013 and 2017, and, two, the adoption could improve further if the leadership and employee involvement and engagement as well as robust processes to monitor and control the LM implementation are strengthened. The factor results were confirmed by a CFA, which showed high factor loadings of over 0.5, as well as high correlations between the factors towards the latent construct.

Further work could be done in two ways. One, selecting more LML's to increase the sample size. Second, do a CFA to check out the EFA results. Another direction could be to relate the LM factors to performance results, so that, claims of high LM adoption could be further validated by correlating with performance data. A third way would be to ask companies to improve on the six identified dimensions and then study whether the LM adoption levels have improved. Action is needed in these areas if Indian manufacturing is to rise to the Prime Minister's call to increase turnover by one trillion USD by 2022.

REFERENCES

Abolhassani, A., Layfield, K., & Gopalakrishnan, B. (2016). Lean and US manufacturing industry: popularity of practices and implementation barriers. *International Journal of Productivity and Performance Management*, *65*(7), 875-897.

Agarwal, A., Sharma, S., Sesha, V., & Mannava, S.B. (2015, October). Development and validation of a comprehensive survey instrument to assess lean implementation. *Proceedings of the Academy of Management Information and Decision Sciences*, *19*(2), 1-5.

Alsmadi, M., Almani, A., & Jerisat, R. (2012). A comparative analysis of Lean practices and performance in the UK manufacturing and service sector firms. *Total Quality Management*, *23*(4), 381-396.

Belekoukiasa, I., Garza-Reyesb, J.A., & Kumar, V. (2014). The impact of lean methods and tools on the operational performance of manufacturing organizations. *International Journal of Production Research*, *52*(18), 5346-5366.

Bhasin, S. (2012). Prominent obstacles to lean. *International Journal of Productivity and Performance Management*, *61*(4), 403-425,

Camuffo, A., & Gerli, F. (2018). Modeling management behaviors in lean production Environments. *International Journal of Operations & Production Management*, *38*(2), 403-423.

Chauhan, G., & Singh, T.P. (2012). Measuring parameters of lean manufacturing realization. *Measuring Business Excellence*, *16*(3), 57-71.

Chen, J.C., Lib, Y., & Shady, B.D. (2010). From value stream mapping toward a lean/sigma continuous improvement process: an industrial case study. *International Journal of Production Research*, *48*(4), 1069-1086.

Cho, E. (2016). Making Reliability Reliable: A Systematic Approach to Reliability Coefficients. *Organizational Research Methods*, pp. 1-32.

Cho, E., & Kim, S. (2014, November 17). *Cronbach's coefficient alpha: well-known but poorly understood*. Organisational Research Methods. DOI: 10.1177/1094428114555994

Chowdary, B.V., & George, D. (2011). Improvement of manufacturing operations at a pharmaceutical company: A lean manufacturing approach. *Journal of Manufacturing Technology Management*, *23*(1), 56-75.

Chowdary, B.V., & George, D. (2011). Improvement of manufacturing operations at a pharmaceutical company: A lean manufacturing approach. *Journal of Manufacturing Technology Management*, *23*(1), 56-75.

Cory, R.A., Hallam & Jerome Keating. (2014). Company Self-Assessment of Lean Enterprise Maturity in the Aerospace Industry. *Journal of Enterprise Transformation*, *4*(1), 51-71.

De Toni, A., & Tonchia, S. (1996). Lean organization, management by process and performance measurement. *International Journal of Operations & Production Management*, *16*(2), 221-236.

Fahmi, S.M., & Abdelwahab, T.M. (2012, July 3 – 6). Case Study: Improving Production Planning in Steel Industry in Light of Lean Principles. *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management* (pp. 2489-2497). Istanbul, Turkey.

Fahmi, S.M., & Abdelwahab, T.M. (2012, July 3–6). Case Study: Improving Production Planning in Steel Industry in Light of Lean Principles. *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management* (pp. 2489-2497). Istanbul, Turkey.

Ferdousi, F., & Ahmed, A. (2009, September). An Investigation of Manufacturing Performance Improvement through Lean Production: A Study on Bangladeshi Garment Firms. *International Journal of Business and Management*, *4*(9), 106-116.

Fuentes, J.M., & Sacristán-Díaz, M. (2012). Learning on lean: a review of thinking and Research. *International Journal of Operations & Production Management*, *32*(5), 551-582.

Gao, S., & Low, S.P. (2014). Impact of Toyota Way Implementation on Performance of Large Chinese Construction Firms. *Journal of Professional Issues in Engineering Education & Practice*, *140*(3), 1-12.

Ghosh, M. (2012). Lean manufacturing performance in Indian manufacturing plants. *Journal of Manufacturing Technology Management*, *24*(1), 113-122.

Graham, J.M. (2006). Congeneric and (Essentially) Tau-Equivalent Estimates of Score Reliability What They Are and How to Use Them. *Educational and Psychological Measurement*, *66*(6), 930-944.

Gupta, V., Acharya, P., & Patwardhan, M. (2013). A strategic and operational approach to assess the lean performance in radial tyre manufacturing in India. *International Journal of Productivity and Performance Management*, *62*(6), 634-651.

Hallam, C.R.A., & Keating, J. (2014). Company Self-Assessment of Lean Enterprise Maturity in the Aerospace Industry. *Journal of Enterprise Transformation*, *4*(1), 51-71.

Hasle, P., Bojesen, A., Jensen, P.L., & Bramming, P. (2012). Lean and the working environment: a review of the literature. *International Journal of Operations & Production Management*, *32*(7), 829-849.
Hedeker, Gibbons, & Waternaux. (1999). Sample size estimation for longitudinal designs with attrition. *Journal of Educational and Behavioral Statistics*, *24*, 70-93.
Hopp, W.J., & Spearman, M.L. (2004). To Pull or Not to Pull: What Is the Question. *Manufacturing & Service Operations Management*, *6*(2), 133-148.
Jacquemont, D. (2014). The Lean Management Enterprise: A system for daily progress, meaningful purpose, and lasting value. *McKinsey and Company*, pp. 1-164.
Jadhav, J.R., Mantha, S.S., & Rane, S.B. (2015), Roadmap for Lean implementation in Indian automotive component manufacturing industry: comparative study of UNIDO Model and ISM Model. *Journal Industrial Engineering International*, *11*, 179-198.
Jasti, N.V.K., & Kurra, S. (2017). An empirical investigation on lean supply chain management frameworks in Indian manufacturing industry. *International Journal of Productivity and Performance Management*, *66*(6), 699-723.
Jasti, N.V.K., & Kodali, R. (2014). Validity and reliability of lean enterprise frameworks in Indian manufacturing industry. *International Journal of Lean Six Sigma*, *5*(4), 361-391.
Jasti, N.V.K., & Kodali, R. (2016). An empirical study for implementation of lean principles in Indian manufacturing industry. *Benchmarking: An International Journal*, *23*(1), 183-207.
Kalton, G. (1983). *Introduction to survey sampling*. Sage Publications.
Karim, A., & Kazi Arif-Uz-Zaman, A. (2013). A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations. *Business Process Management Journal*, *19*(1), 169-196.
Khadse, P.B., Sarode, A.D., & Wasu, R. (2013, September). Lean Manufacturing in Indian Industries a Review. *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, *3*(1), 175-181.
Kotter, J.P. (1996). *Leading Change*. Harvard Business School Press.
Kotter, J.P. (2007, January). Leading change. why transformational efforts fail. *HBR*, pp. 1-9.
Kotter, J.P. (2014, January). Leading change: why transformation efforts fail. *HBR*, pp. 1-9.
Kotter, J.P., & Cohen, D.S. (2002). *The heart of change*. Harvard Business School Press.
Krafcik, J.F. (1988, Fall). Triumph of The Lean Production System. *Sloan Management Review*, *30*(1), 41-52.
Krafcik, J.F. (1989). A new diet for US manufacturing. *Technology Review*, *92*(1), 28-36.
Krishna, V., & Parveen, C.M. (2013, July 3-5). Comparative study of lean manufacturing tools used in the manufacturing firms and the service sector. *Proceedings of the World Congress on Engineering 2013*. WCE 2013, London, U.K.
Liker, K.J. (2004, January 1). *The Toyota way*. New York, NY: McGraw Hill Education. ISBN-10: 0071392319
Losonci, D., Kasha, R., Demeter, K., Heidrich, B., & Jenei, I. (2017). The impact of shop floor culture and subculture on lean production practices. *International Journal of Operations & Production Management*, *37*(2), 205-225.
Lucato, W.C., Calarge, F.A., Junior, M.L., & Calado, R.D. (2014). Performance evaluation of lean manufacturing implementation in Brazil. *International Journal of Productivity and Performance Management*, *63*(5), 529-549.
Maasouman, M.A., & Demirli, K. (2015). Assessment of Lean Maturity Level in Manufacturing Cells. *IFAC-PapersOnLine*, *48*(3), 1876-1881.
Matthias, Z., & Hagemann, D. (2015). Testing the Unidimensionality of Items Pitfalls and Loopholes. *European Journal of Psychological Assessment*, *31*(4), 231-237.
McNeish, D. (2017, May 29). Thanks Coefficient Alpha, We'll Take It From Here. *Psychological Methods, advance online publication*, pp. 1-22. http://dx.doi.org/10.1037/met0000144

Mohapatra, S.S., & Mohanty, S.R. (2007, January). Lean manufacturing in continuous process industry: an empirical study. *Journal of Scientific and Industrial Research*, *66*, 19-27.

Mostafa, S., Dumrak, J., & Soltan, H. (2013). A framework for lean manufacturing implementation. *Production & Manufacturing Research: An Open Access Journal*, *1*(1), 44-64. DOI: 10.1080/21693277.2013.862159

Narasimhan, R., Swink, M., & Kim, S.W. (2006). Disentangling leanness and agility: An empirical investigation. *Journal of Operations Management*, *24*, 440-457.

Narayanamurthy, G., & Gurumurthy, A. (2016). Systemic leanness an index for facilitating continuous improvement of lean implementation. *Journal of Manufacturing Technology Management*, *27*(8), 1014-1053.

Nawanir, G., Teong, L.K., & Othman, S.N. (2013). Impact of lean practices on operations performance and business performance: Some evidence from Indonesian manufacturing companies. *Journal of Manufacturing Technology Management*, *24*(7), 1019-1050.

Nenni, M.E., Giustiniano, L., & Pirolo, L. (2014), Improvement of Manufacturing Operations through a Lean Management Approach: A Case Study in the Pharmaceutical Industry. *International Journal of Engineering Business Management, Special Issue: Innovations in Pharmaceutical Industry*, pp. 1-6.

Nesensohn, C., Bryde, D., Ochieng, E., & Fearon, D. (2014). Maturity and Maturity Models in Lean Construction. *Australasian Journal of Construction Economics & Building*, *14*(1), 45-59.

Nightingale, D.J., & Mize, J.H. (2002). Development of a Lean Enterprise Transformation Maturity Model. *Information Knowledge Systems Management*, *3*, 15-30.

O'hEocha, M. (2000). A study of the influence of company culture, communications and employee attitudes on the use of 5Ss for environmental management at Cooke Brothers Ltd. *The TQM Magazine*, *12*(5), 321-330.

Pakdil, F., & Leonard, K.M. (2014). Criteria for a lean organization: development of a lean assessment tool. *International Journal of Production Research*, *52*(15), 4587-4607.

Panwar, A., Jain, R., & Rathore, A.P.S. (2015). Lean implementation in Indian process industries – some empirical evidence. *Journal of Manufacturing Technology Management*, *26*(1), 131-160.

Perera, P.S.T., & Perera, H.S.C. (2013). Developing a Performance Measurement System for Apparel Sector Lean Manufacturing Organizations in Sri Lanka. *Vision*, *17*(4), 293-301. © 2013 MDI, SAGE Publications, Los Angeles, London, New Delhi, Singapore, Washington DC. DOI: 10.1177/0972262913505371. http://vision.sagepub.com

Prasad, S., Khanduja, D., & Sharma, S.K. (2016). An empirical study on applicability of lean and green practices in the foundry industry. *Journal of Manufacturing Technology Management*, *27*(3), 408-426.

Prashar, A. (2014). Redesigning an assembly line through Lean-Kaizen: An Indian case. *The TQM Journal*, *26*(5), 475-498.

Rajenthirakumar, D., Mohanram, P.V., & Harikarthik, S.G. (2011, June). Process Cycle Efficiency Improvement Through Lean: A Case Study. *International Journal of Lean Thinking*, *2*(1), 46-58.

Ramesh, V., & Kodali, R. (2012). A decision framework for maximizing lean manufacturing performance. *International Journal of Production Research*, *50*(8), 2234-2251.

Roy, R.N., & Guin, K.K. (1999). A proposed model of JIT purchasing in an integrated steel plant. *International Journal of Production Economics*, *59*, 179-187.

Sakakibara, S., Flynn, B.B., & Schroeder, R.G. (1993). A framework and measurement instrument for just-in-time Manufacturing. *Production and Operations Management*, *2*(3), 177-194.

Samuel, D., Found, P., & Williams, S.J. (2015). How did the publication of the book The Machine That Changed the World change management thinking? Exploring 25 years of lean literature. *International Journal of Operations & Production Management*, *35*(10), 1386-1407.

Sánchez, A.M., & Pérez, M.P. (2001). Lean indicators and manufacturing strategies. *International Journal of Operations & Production Management*, *21*(11), 1433-1452.

Sangwan, K.S., Bhamu, J., & Mehta, D. (2014). Development of lean manufacturing implementation drivers for Indian ceramic industry. *International Journal of Productivity and Performance Management*, *63*(5), 569-587.
Scaffede, R. (2002, Autumn). What it takes to turn manufacturing lean: the experience of Donnelly Corporation. *Journal of Organisational Excellence*, pp. 1-16.
Schlesselman, J.J. (1973). Planning a longitudinal study: i. Sample size determination. *Journal of Chronic Diseases*, *26*, 553-560.
Sezena, B., Karakadilarb, I.S., & Buyukozkan, G. (2012). Proposition of a model for measuring adherence to lean practices: applied to Turkish automotive part suppliers. *International Journal of Production Research*, *50*(14), 3878-3894.
Shah, R., & Ward, P.T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management*, *21*, 129-149.
Shah, R., & Ward, P.T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*, *25*(4), 785-805.
Shang, G., & Pheng, L.S. (2012). The adoption of Toyota Way principles in large Chinese construction firms. *Journal of Technology Management in China*, *7*(3), 291-316.
Sharma, V., Dixit, A.R., & Qadri, M.A. (2015). Impact of lean practices on performance measures in context to Indian machine tool industry. *Journal of Manufacturing Technology Management*, *26*(8), 1218-1242.
Silva, S.K.P.N. (2012). Applicability of VSM in the apparel industry in Sri Lanka. *International Journal of Lean Thinking*, *5*(1), 36-41.
Singh, B. (2016). Identification of lean implementation hurdles in Indian industry. *International Journal of Social, Behavioural, Educational, Economic, Business and Industrial Engineering*, *10*(5), 1516-1520.
Singh, B., & Sharma, S.K. (2009). Value stream mapping as a versatile tool for lean implementation: an Indian case study of a manufacturing firm. *Measuring Business Excellence*, *13*(3), 58-68.
Singh, B., Garg, S.K., Sharma, S.K., & Grewal, C. (2010). Lean implementation and its benefits to production industry. *International Journal of Lean Six Sigma*, *1*(2), 157-168.
Singh, M.P., Meena, R., & Panwar, A. (2016). A survey of the adoption of lean practices in Indian manufacturing sector. *International Journal of Industrial Engineering Research and Development (IJIERD)*, *7*(2), 52-62.
Singh, R., Chopra, A., & Kalra, P. (2014, May). Value stream mapping as a tool to identify the opportunities of lean techniques: an auto industry case study. *International Journal of Science and Research*, *3*(1), 1829-1833.
Spear, S., & Bowen, H.K. (1999, September-October). Decoding the DNA of the Toyota Production System. *Harvard Business Review*, *77*(5), 96-106.
Taj, S. (2008). Lean manufacturing performance in China: assessment of 65 manufacturing plants, *Journal of Manufacturing Technology Management*, *19*(2), 217-234.
Taj, S., & Morosan, C. (2011). The impact of lean operations on the Chinese manufacturing performance. *Journal of Manufacturing Technology Management*, *22*(2), 223-240.
Thanki, S.J., & Thakkar, J. (2014). Status of lean manufacturing practices in Indian industries and government initiatives A pilot study. *Journal of Manufacturing Technology Management*, *25*(5), 655-675.
Tortorella, G.L., de Castro Fettermann, D., Frank, A., & Marodin, G. (2018). Lean manufacturing implementation: leadership styles and contextual variables. *International Journal of Operations & Production Management*, *38*(5), 1205-1227.
Van De Geer, J.P. (1993). *Multivariate analysis of categorical data: applications. Advanced Quantitative Techniques in the Social Sciences 3*. Sage Publications.
Vinodh, S., & Joy, D. (2012). Structural Equation Modelling of lean manufacturing practices. *International Journal of Production Research*, *50*(6), 1598-1607.

Vinodh, S., Selvaraj, T., Chintha, S.K., & K E K, V. (2015). Development of value stream map for an Indian automotive components manufacturing organization. *Journal of Engineering, Design and Technology*, *13*(3), 380-399

Vinodh, S., Shivraman, K.R., & Viswesh, S. (2011). AHP-based lean concept selection in a manufacturing organization. *Journal of Manufacturing Technology Management*, *23*(1), 124-136.

Wan, H., & Chen, F.F. (2008). A leanness measure of manufacturing systems for quantifying impacts of lean initiatives. *International Journal of Production Research*, *46*(23), 6567-6584.

Widaman, K.F. (1993). Common Factor Analysis Versus Principal Component Analysis: Differential Bias in Representing Model Parameters. *Multivariate Behavioral Research*, *28*(3), 263-311.

Womack, J., & Jones, D. (1996). *Lean Thinking – Banish Waste and Create Wealth in your Corporation*. London: Simon & Schuster.

Womack, J., Jones, D., & Roos, D. (1990). *The Machine That Changed the World*. New York: Rawson Associates.

Yadav, O.P., Nepal, B., Goel, S.P., & Mohanty, R.P. (2010). Insights and learnings from lean manufacturing implementation practices. *International Journal of Services and Operations Management*, *6*(4), 398-422.

Yogesh, M., & Prabagaran, S. (2016). Study on Implementation of Lean Manufacturing Tools and Techniques. *International Journal of Applied Engineering Research*, *11*(5), 3289-3293.