The impact of lean practices on operational performance- An empirical investigation of Indian process industries

Abstract

In deciding to adopt lean manufacturing, it is imperative to investigate where and how lean practices are most needed to influence manufacturing and business performance. Such an investigation becomes indispensable when lean thinking is to be considered in a production arrangement different to the conventional, repetitive, high-volume, stable-demand, discrete-manufacturing environment. This study provides explanations of how performance is improved through the adoption of lean practices in process industries. This is a relatively under-researched area compared to the performance effects associated with the introduction and implementation of lean principles in traditional, discrete manufacturing. Based on a survey of Indian process industries, this study attempts to develop an empirical relationship between lean practices and performance improvement through the use of multivariate statistical analysis. The findings have led to the conclusion that lean practices are positively associated with timely deliveries, productivity, first-pass yield, elimination of waste, reduction in inventory, reduction in costs, reduction in defects and improved demand management. However, within a process-industry context, lean practices related to pull production were found to have a marginal impact on performance improvement. A detailed discussion of the findings along with their theoretical and managerial implications is provided in the paper.

Keywords - Process industry; India; lean practices; performance improvement; lean manufacturing

Paper type - Research paper

1. Introduction

In the global manufacturing arena, India is becoming a favourite manufacturing destination (Pannizolo et al., 2012). Becoming an international manufacturing hub has not only generated a plethora of opportunities but also forced Indian process industries to face heightened competition, local as well as global. To remain competitive in contemporary, dynamic markets these industries are required to counter several challenges. Two prominent challenges are to improve manufacturing efficiency and supply chain performance (Jaiganesh and Sudhahar 2013). Another challenge is to improve quality (Poongothai and Arul 2011). Furthermore, Dogra *et al*. (2011) found inventory turns to be low in Indian process industries and, therefore, working capital is tied up for longer periods in this sector. Equipment-related problems such as high numbers of reworks and rejections, frequent breakdowns, high accident rates and high pollution also persist in Indian process industries. Additionally, due to the inherent characteristics of process industries, energy consumption is high (Wesseling et al., 2017). Moreover, the condition is exacerbated by the high cost of energy in India. Consequently, the process industry sector is pushing hard to find ways to cut energy consumption.

Therefore, the Indian process industry needs to strive for operational excellence and restructure its operations to remain globally competitive and to increase profits and productivity. As a result, the need to supplant antiquated production methods with 21st century manufacturing methodologies, such as lean, has been argued for and is being observed in process industries (Lyons et al. 2013; Vlachos, 2015).

Mathur, Mittal and Dangayach (2012) emphasize that lean targets the elimination of non-value-adding activities, thus reducing production cost. Radnor and Johnston (2013) claim that lean helps both in process improvement and customer service. Moreover, the manufacturing management literature suggests that lean manufacturing is one of the most effective modern management tools to cope with contemporary competitive challenges (Martínez-Jurado and Moyano-Fuentes, 2014)

Recently, Piercy and Rich (2015) found that the adoption of lean thinking can also result in many sustainability outcomes. Therefore, lean adoption can result in operational, financial and environmental performance improvements (Negrão, Godinho, and Marodin, 2017).

There is some evidence of the adoption of formal, lean practices in Indian process industries (Upadhye, Deshmukh, and Garg 2010; Panizzolo *et al.* 2012; Panwar, Jain, and Rathore 2015b). However, the level of adoption is still not encouraging (Panwar, Jain, and Rathore 2015b), and an ambiguity concerning performance improvement from lean is discernible. This hesitation to adopt lean practices in Indian process industries resonates with the conflicting information presented in some of the published papers on the benefits of lean. Some researchers found that lean is perceived to be quite beneficial for process industries such as steel, food pharmaceuticals and textiles (Abdulmalek and Rajgopal 2007; Gebauer, Kickuth, and Friedli 2009; Manfredsson 2016), whereas, for the same industrial sectors, some researchers (Hokoma *et al.* 2008; Hokoma *et al.* 2010; Small *et al.* 2011) perceive lean to be less beneficial in comparison with other initiatives such as TQM or MRP.

Secondly, the literature on lean implementation in process industries is dominated by case studies. Empirical studies such as surveys regarding lean implementation issues with a specific focus on process industries are scarce (Gebauer, Kickuth, and Friedli 2009; Lyons et al. 2013). Similarly, although there are prior published case studies on the implementation of lean in Indian process industries, their scope is confined to a particular firm or a particular type of process industry (Roy and Guin 1999; Dhandapani et al. 2004; Gupta, Acharya and Patwardhan 2013; Upadhye Deshmukh and Garg 2010). Therefore, their results cannot be generalized, as highlighted by Gupta, Acharya and Patwardhan (2013).

Thirdly, with the unique process industry characteristics, the adoption of lean thinking in process industries is not as straightforward as it is in discrete industries (Panwar *et al*. 2015). Lyonnet and Toscano (2014) also warn that the diffusion of lean practices should be carried out carefully for a distinct industrial set-up. For instance, in process industries, the product is not in separable units and, therefore, the applicability of certain lean practices such as kanban, pull systems and cellular manufacturing is challenging and can be unfruitful (Jimenez *et al*. 2012).

Additionally, successful operationalization of new manufacturing practices can depend on national culture (Cagliano et al., 2011). Kull et al. (2014) claim that performance improvement through the adoption of lean practices is also influenced by the national culture. Indian national culture is characterized by high 'power-distance' which means that employees generally are unquestioning in following the instructions of their superiors and there is a working environment where the source of expertise is highly respected. Indians favour standard procedures to be followed to avoid uncertainty and reduce risk. Indian culture is also characterized by high group collectivism: Indians prefer to work in a group having typical commonalities such as caste, position or qualifications. Similarly, Indian society is future oriented and conservative, therefore, individuals often plan for a secured future (Rao, 2013). However, whether such characteristics stimulate or otherwise the adoption of lean practices and their impact on operational performance in Indian industries has not been studied.

The review of the literature confirms that there have been no publications focused upon quantifying the effects of lean practices on performance in the Indian process sector. Panwar, Jain and Rathore (2015b) carried out a survey of Indian process industries and ranked the lean practices used i and challenges to lean implementation. Panwar, Jain and Rathore (2015a) compared the use of lean practices between continuous and batch process industries. However, neither of these studies explore the extent to which lean practices impact performance.

The objective of this paper is to quantify the effect of lean practices on select performance improvement metrics in Indian process industries. A multivariate statistical analysis is used to examine the causal relationships between performance improvement and the adoption of lean practices. First, the lean practices are grouped into higher-level, lean constructs through an exploratory factor analysis. Similarly, performance measures are also clubbed together into higher level factors. Subsequently, multiple linear regression analysis is carried out between lean constructs and performance constructs to develop statistical models for analyzing the causal relationship between lean constructs and performance improvement. The results of the analyses are discussed in detail including important insights concerning the theoretical and managerial implications of this research.

The remainder of the paper is organized as follows. In section 2, a comprehensive literature review is presented highlighting the scope of lean and performance improvements from the implementation of lean initiatives. The research methodology is explained in section 3 followed by a summary of the research findings in section 4. Section 5 provides a discussion of the findings along with the theoretical and managerial implications. Finally, section 6 concludes the paper with a summary of the contribution, limitations, and suggestions for future research.

2. Overview of related literature

2.1 Defining lean manufacturing and lean practices

Sohal (1996) defined lean manufacturing as a manufacturing system which aims to eliminate unnecessary processes, align processes to maintain a continuous flow, and solve problems through continuous improvements. Interestingly, as the applicability of lean increased across industries and across business areas the philosophy has enriched itself from the incorporation of newer principles and newer practices (Holweg, 2007). Consequently, lean manufacturing acquired newer definitions to suit newer applications. However, a confusion about "*what is lean exactly?"* is also evident. Lean was argued to have 'strategic' and 'operational' dimensions (Hines, 2004) and 'philosophical' as well as 'practical' dimensions (Shah and Ward, 2007). Therefore, it became difficult to define lean in a clear and unanimously acceptable manner. However, Pettersen (2009) synthesized previous literature on the fundamentals of lean and claimed that the literature is *'reasonably consistent'* concluding that lean comprises of just-in-time production, efficient resource utilization, continuous improvement strategies, defect control, standardization of operations and scientific management techniques. The definition given by Shah and Ward (2003) appears to be nearest to the conclusion made by Pettersen (2009).

In their seminal work, Shah and Ward (2003) defined lean production as a multi-faceted approach that includes a wide range of management practices such as just-in-time, quality systems, work teams, cellular manufacturing and supplier management. According to the authors, "*The core thrust of lean production is that these practices can work synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste"*. It is understandable from this definition that a wide variety of the lean practices can be grouped into homogeneous sets which aim to achieve a particular target associated with implementing lean such as elimination of waste, quality conformance, demand management and reduction of costs.

Shah and Ward (2003) describe 22 lean practices as the elements of lean manufacturing. Important lean practices that the authors identified are set-up reduction, quick changeover techniques, statistical process control, *kanban*, supplier partnership, continuous improvement, quality management, total productive maintenance (TPM), foolproof systems, standard operating procedures, and mixed model production. The authors group lean practices into four lean principles: TPM (Total Productive Maintenance), TQM (Total Quality Management), HRM (Human Resource Management) and JIT (Just-in-Time).

It is important to note that a few lean practices aim to bring general fitness to the company in terms of agility, resilience and capability to deal with change, such as 5S and kaizen. These lean practices work as a foundation for the adoption of more technical lean practices that target a particular kind of performance contribution such as 'pull production' (Bortolotti et al. 2015). According to Bortolotti et al. (2015), HRM and TPM lean bundles proposed by Shah and Ward (2003) consist of general lean practices which can be implemented first to build a strong foundation for the adoption of TQM, and JIT bundles to achieve a specific type of performance. Additionally, Bamford et al. (2015) suggested that it is not necessary that all the lean tools should be applied to achieve improvements. Conversely, it is true that even using the lean philosophy partially within certain operating constraints can result in dramatic outcomes with respect to operational performance.

2.2 Performance measurement

Performance measurement is the process of estimating the output of actions that are carried out with respect to a job (Neely, Gregory and Platts 2005). Koufteros, Verghese and Lucianetti (2014) argue that performance measurement affects organizational capabilities and consequently helps a firm with meeting its targets. According to Garengo and Sharma (2014), a performance measurement system provides significant support for improvement in managerial practices. de Waal and Kourtit (2013) describe three quantitative measures of performance (profit, cost and revenue) and twenty qualitative measures of performance. However, Karim and Arif-Uz-Zaman (2013) observed that it is often overwhelming for the manufacturers if the number of performance measures is very large.

An organization's overall performance can have several contributory dimensions, for instance, operational, financial, and environmental (Dey and Cheffi.2013). However, it is operational performance, where the lean practices are regarded as having the most profound impact (Shah and Ward, 2003; Fullerton and McWatters, 2003). Shah and Ward (2003) describe six areas of operational performanc:; unit manufacturing cost, first pass yield, lead time, on-time delivery, scrap and rework cost, and productivity. However, Ghosh (2012) argues that inventory and space requirements also improve due to operational performance improvement efforts. Similarly, Lyons et al (2013) demonstrated that due to the implementation of lean practices, the process of demand management can also be improved in process industries.

2.3 Impact of lean practices on performance improvement in process industries

Lean has provided applications in many industries other than automotive or discrete manufacturing (Yang *et al.* 2015), for instance, process (Lyons et al. 2013; Panwar, Jain, and Rathore 2015b), service (Piercy and Rich 2009), health (Costa and Godinho Filho, 2016) and transportation (Villarreal, Garza-Reyes, Kumar, 2016).

Manfredsson (2016) claims, with an example from the textile industry, that lean is transferable to different types of industries However, according to Susilawati *et al.* (2015) applying lean thinking in different sectors is a difficult process.

Researchers have used statistical techniques such as regression models and structural equation models to explain the relationship between the extent of lean practices adoption and critical performance metrics (Khanchanapong *et al*. 2014). For example, Dong, Carter, and Dresner (2001) used structural equation modelling to understand the effect of just-in-time (JIT) purchasing on cost reduction. Based on regression models, Fullerton, McWatters, and Fawson (2003) claimed that the higher the extent to which JIT practices are used the greater the profitability in US firms. By using a similar model between lean practices and operational performance factors, Shah and Ward (2003) were able to explain 23% variance in operational performance. In a global survey of 136 manufacturing firms in Japan, Korea, Germany and USA, Abdallah and Matsui (2007) found that the implementation of JIT was responsible for 21.4% variance in operational performance, and the inclusion of TPM practices could explain a further 8% variance in operational performance. Nawanir, Teong, and Othman (2013) found a positive relationship between lean practices and operational performance in Indonesian firms in terms of quality, inventory minimization, delivery, productivity and cost reduction. Based on a survey of US firms, Hofer, Eroglu, and Hofer (2012) found that performance benefits could be achieved to a greater extent if the internally-focused and externally-focused lean practices were implemented concurrently. Chavez et al. (2013) demonstrated that internal lean practices had a positive effect on quality, cost, delivery and flexibility. Gebauer, Kickuth, and Friedli (2009) claimed that supplier-related lean practices also have an influential effect on quality.

For Indian manufacturing firms, Ghosh (2012) claimed that the implementation of lean practices could explain 20% variance in productivity, 24% variance in manufacturing lead time and 25% variance in first pass correct output. Surprisingly, TPM was found to have an adverse effect on productivity and manufacturing lead time. The paper argued that the plants participating in the survey were old and the level of implementation of TPM was low. However, the author examined the effect of implementation of only a few lean practices on only three operational dimensions.

Researchers have also estimated the financial benefits in terms of savings after the implementation of lean practices. For instance, Cogdill *et al.* (2007) found that through the adoption of lean manufacturing a pharmaceutical company could achieve $6million annual savings due to a reduction in labour cost. Kumar *et al*. (2006), in a study of UK SMEs, found that the implementation of lean six sigma resulted in a decrease in machine downtime by $40,000, reduction in WIP inventory by$33,000 and reduction in accidents to a of value $20,000. Laureani and Antony (2010) found a cost saving in human resource management through the implementation of lean practices worth $1.3 million in a service company. In a study of a furniture-making company in Michigan, Miller, Pawloski and Standridge (2010) found that the application of kaizen resulted in savings of $1950 daily and annual savings of $100,000 in transportation costs. In Portugal, Moreira and Pais (2011) found that through the application of a lean practice (SMED) a mould making company could save £362,960 annually.

However, a few studies provide mixed results about performance improvement from the adoption of lean practices. Shah and Ward (2003) claimed that the extent of the use of JIT lean practices are less in process industries in comparison to TPM practices. The authors argue that the process industries aim for high capacity utilization which motivates them to adopt TPM practices. On the other hand, Danese, Romano and Bortolotti (2012) reported that JIT practices have a positive impact on operational performance such as efficiency and delivery. However, JIT supply practices were found not to have a significant effect on efficiency and delivery. Similar results are provided by Losonci and Demeter (2013) and Hofer, Eroglu, and Hofer (2012). Furthermore, contextual factors such as geographical location, type of production system and inherent characteristics play a vital role with regard to the extent of the performance improvement from lean (Melton 2005; Piercy and Rich 2015; Dora, Kumar and Gellynck 2016;).

In summary, our review of the related literature suggests that the adoption of lean practices do positively influence performance. However, the majority of such studies have been focused on discrete manufacturing. We found such studies in process industries to be somewhat limited. The present study is an attempt to address this gap in which our focus is to quantify the effect of select lean practices on key performance metrics in process industries.

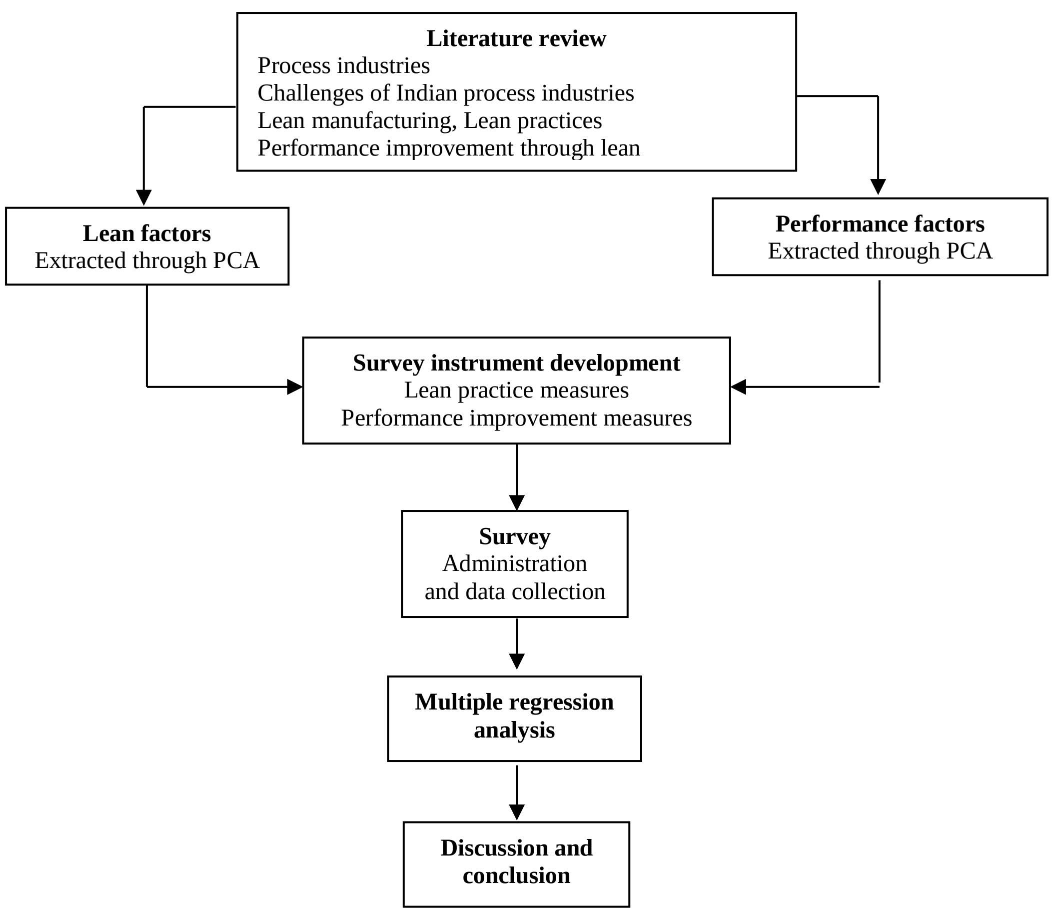
3. Research methodology

The research framework is illustrated in Fig. 1. Our study is grounded in the existing literature and makes use of an empirical-driven, methodological approachy. The overall research framework is divided into multiple key activities as described in the following sections.

3.1 Survey instrument

Prior studies suggest that a structured questionnaire is the most appropriate tool to collect survey data in order to explore the relationship between lean practices and performance improvement (Dong, Carter, and Dresner 2001). Therefore, a structured questionnaire was developed from a comprehensive literature survey within the context of lean implementation and operational performance in process industries. After developing a primary draft, the questionnaire was sent to the managing director of a steel processing plant, one production manager at a refinery and two professors with experience in teaching operations management and lean manufacturing, for their feedback. According to the suggestions of these experts, the questionnaire was modified to increase its appropriateness and adherence to relevant issues.

Figure 1: Research framework



3.2Measurement scale

Prior research has varied in terms of the number of lean practices considered in the study of performance improvement. For example, Shah and Ward (2003) suggested 22 lean practices to develop practice bundles of lean manufacturing, whereas Fullerton and McWatters (2001) identified ten lean practices to study the performance improvement through lean adoption. Likewise, Ghosh (2012) proposed a set of seven lean practices to estimate performance improvement in Indian manufacturing firms. However, Panwar, Jain, and Rathore (2015b) found that certain lean practices such as cellular manufacturing and focused factory have only a limited application in process industries due to their unique characteristics. In a study, exclusively for process industries, Lyons *et al*. (2013) cited twenty-three lean practices. Based on these studies, eighteen lean practices were identified to investigate their relationship with performance improvement in Indian process industries. Table 1 lists the lean practices used in the present study and their literature source. A five-point Likert scale was developed to measure the extent of the use of lean practices (Malhotra 2006). The Likert scale ranged from 1 = not implemented to 5 = complete implementation.

Table 1: Measures of lean practices

Lean practices	**Literature source**					
	Shah and Ward (2003)	Fullerton and McWatters(2001)	Doolen and Hackers (2005)	Lyons et al.(2013)	Ghosh (2012)	Present Study
Total productive maintenance	X	X	X	X	X	X
5S			X	X		X
Quality management programme	X	X	X	X		X
Work standardization			X	X		X
Statistical process control	X			X	X	X
Continuous improvement programmes	X			X		X
Visual control				X		X
Long term relationship with suppliers	X		X	X		X
Flexible and cross functional teams	X	X	X	X	X	X
Small number of supplier	X			X		X
Bottleneck/ constraint removal	X					X
Supplier integration and partnership	X		X	X		X
New equipment and technology						X
Lot-size reduction	X		X			X
JIT purchasing		X		X		X
Quick changeover techniques	X		X			X

Pull production	X		X	X	X	X
Production levelling	X	X	X	X		X

Although based on two prior studies (Shah and Ward 2003; Ghosh 2012), initially, a seven-item scale was developed to measure the performance improvement, ‘demand management’ was added later as recommended by Lyons *et al.* (2013). Thus this study includes an eight-item scale for operational performance measurement. Table 2 lists the performance measurement items and their literature source. During the survey, respondents were asked to rate the change in operational performance as a result of the implementation of lean practices in question by using a five-point Likert scale, where 1= very low to 5= very high.

Table 2: Operational performance measures

Operational performance measures	Shah and Ward (2003)	Ghosh (2012)	Present Study
Inventory levels		X	X
Timely deliveries	X	X	X
Level of various costs	X	X	X
Level of wastes	X		X
Productivity	X	X	X
Demand management			X
Defect levels	X		X
First pass yield	X	X	X

3.3 Survey administration

The survey was sent to 500 randomly selected process industry firms out of a very large database maintained in a directory of ISO9001 certified process industries in India. The target respondents were high-level managers with responsibility for production. As usually is the case with any large study, the initial response rate was low. To boost the response rate, the initial survey was followed up with telephone requests and email reminders. In the end, a total of 121 responses (that is, 24.2%) were received. Considering the response rate of other similar studies, we believe that it was a good response rate for a typical large survey in an Indian context. Ghosh (2012) achieved a response rate of 20% in the study of lean implementation in Indian manufacturing firms. Similarly, Pandey, Garg, and Shankar (2010) and Upasani (2012) achieved a response rate of only 18.02% and 17.5% respectively. Table 4 provides the details of rhe respondents' characteristics.

Table 4: Sample demographics

	Sample (%)		Sample (%)
Respondent's work title		**Type of product**	
General Manager/ Director	16.5	Cement	9.1
Production Manager	42.1	Ceramics	3.3
Operations Manager	30.5	Chemicals	13.2
Others	10.9	Food and drink	22.3
		Pharmaceutical	5.0
No. of Employees		Plastic and rubber	3.3
<100	18.2	Steel	17.4
101-500	39.7	Textile	1.7
501-1000	19.8	Petroleum	10.7
>1000	22.3	Sugar	3.3
		Beverage	6.6
Size		Paper	3.3
Large	81.8	Others	0.8
Small	18.2		

3.4 Non-response bias and common method bias

Miller and Smith (1983) suggest that generalizability of findings considerably increase if non-response bias is avoided. Therefore, a non-response bias test was performed based on the approach suggested by Armstrong and Overton (1977). Five items were chosen randomly from the questionnaire to compare the first and the last 15 filled questionnaires using the Chi-squared test. The significance values of all the picked items were greater than 0.01 which confirmed that non-response bias did not exist.

Another concern was to examine the data for common method bias since the respondents were asked to give their opinion on two sets of variables or constructs (Podsakoff *et al.*, 2003). Harman's single factor test using exploratory factor analysis (EFA) was used. EFA synthesized five distinct factors with Eigen values above 1.0 explaining 75.01% of total variance. The first factor explained 30.1% variance which is a small part of the variance. Therefore, the results indicate that the common method bias was not a concern in this study.

4. Data analysis and results

Although many previous studies have synthesized higher-level constructs of lean practices (Shah and Ward, 2003, Bortolotti et al 2015), there is no consensus concerning the composition of the lean constructs among the researchers. As highlighted earlier, Shah and Ward (2003) described four lean constructs whereas Bortolotti et al. (2015) identified three. Also, whenever lean is tried in an environment that is not based on discrete manufacturing, only some lean practices have found to be applicable (Bamford et al., 2015). Therefore, in this study, the lean bundles are synthesized for a process industry context Principal component factor analysis with Varimax rotation was used to extract the minimum number of factors. Only those factors that accounted for a variance greater than one (eigenvalues>1) were extracted (Kim and Mueller, 1978). According to the guidelines of Hair, Anderson, and Tatham (1984), only the items with factor loadings greater than 0.4 were considered for further analysis. Five lean constructs were extracted from the factor analysis (Table 5). The first factor was named '*lean practices set 1'* (LP1). It includes such practices as quality management programmes, visual control, supplier integration, supplier rationalization, and supplier development.

Table 5: Varimax factor rotated component matrix (Lean practices' factors)

Lean practices	**Component**				
	LP1	**LP2**	**LP3**	**LP4**	**LP5**
Supplier rationalization	.950				
Long term relationship	.946				
Supplier integration and partnership	.757				
Visual control	.623				
Quality control	.595				

Cronbach's alpha	**.885**				
JIT purchasing		.892			
Quick changeover techniques		.796			
Lot-size reduction		.776			
Bottleneck/ constraint removal		.584			
Cronbach's alpha		**.802**			
5S			.905		
Total productive maintenance			.862		
Statistical process control			.444		
Cronbach's alpha			**.733**		
Work standardization				.824	
Flexible and cross-functional teams				.709	
New equipment and technology				.509	
Continuous improvement programmes				.485	
Cronbach's alpha				**.779**	
Production levelling					.468
Pull production					.857
Cronbach's alpha					**.600**

The second factor was named 'lean practices set 2*'* (LP2). This factor included lean practices such as JIT purchasing, quick changeover techniques, lot size reduction and bottleneck removal. The third factor, 'lean practices set 3*',* (LP3) comprised 5S, total productive maintenance (TPM), and statistical process control (SPC).

Practices such as continuous improvement programmes, flexible and cross-functional teams, new equipment and technology, and work standardization are considered as '*lean practices set 4'* (LP4). The reason for these practices being loaded into a single factor is that these are equally popular practices in process industries. Pull production and production levelling are primarily used to establish a pull system of production. The fifth factor is named '*lean practices set 5'* (LP5).

It is worth noting that these factors are not exclusive. However, the lean practices are included in the factors to which they contribute the most. Table 5 also illustrates the internal consistency of lean constructs. High values of Cronbach's alpha for each factor confirm the reliability of the instrument and the high degree of indication of a common latent variable. However, to establish discriminant validity, a χ^2 difference test for all the constructs was performed on items in pairs to observe if they are dissimilar from one another. In each case, a two-factor model showed a better fit than a single-factor model, thus supporting the discriminant validity of the construct.

Principal component analysis with varimax rotation was carried out to achieve higher level constructs for performance measures. Kaiser-Mayer-Olkin test (0.751) and Bartlett's test of sphericity (Sig. 0.000) indicate that variables are suitable for factor analysis. Table 6 provides the varimax rotated component matrix with the items that load strongly on each of the extracted factors.

Table 6: Varimax factor rotated component matrix (Performance improvement factors)

Performance improvement measures	**Component**	
	OP_IMP	**QTY_IMP**
Inventory levels	0.765	
Timely deliveries	0.760	
Level of various costs	0.733	
Level of wastes	0.726	
Productivity	0.655	
Demand management	0.410	
Cronbach's alpha	**0.750**	
Defect levels		0.628
First pass yield		0.627
Cronbach's alpha		**0.620**

Six performance improvement areas included in the first factor are inventory levels, timely deliveries, level of various costs, level of wastes, productivity and demand management. Together, these improvements were cumulatively defined as '*operational improvements*' (OP_IMP) based on the notion that the adoption of lean practices helps to achieve operational excellence.

The second factor included the level of defects and first pass yield. Thus, this factor was named '*quality improvement'* (QTY_IMP). The matrices of different factors illustrated that they were unifactorial with Eigenvalues greater than 1. Therefore, the results indicated good construct validity for the developed scales.

4.1Causal relationship between lean factors and operational improvement factors

Multiple regression analysis is used to investigate the causal relationship between independent and dependent variables. According to Field (2009), the predictors should not have zero variance. In the present study, all predictor variables have non-zero variance. Furthermore, the predictor variables should not correlate too highly. Table 7 shows the correlation among predictor variables.

Table 7: Correlation among lean constructs to test multicollinearity

Lean constructs (Predictor variables)	LP1	LP2	LP3	LP4	LP5
LP1	1	.377*	.498*	.408*	.250*
LP2		1	.352*	.462*	.067
LP3			1	.364*	.325*
LP4				1	.130
LP5					1

** Correlation is significant at .05 level (two-tailed)

It is evident from Table 7 that for predictor variables, the value of the correlation coefficient is considerably less than one. Therefore, predictor variables do not show perfect collinearity.

4.3.1 Multiple regression analysis between lean constructs (predictors) and performance factors (outcomes)

A backward stepwise regression method was used for regression analysis. In the backward method, the model calculates the contribution of each variable by judging the significance value. If it is found that the predictor variable does not contribute significantly to the model in the prediction of the outcome variable according to the removal criteria, that predictor variable is removed from the model (Andy Fields. 2009).

Table 8 summarizes the results of different models synthesized from the multiple regression**.**

Table 8: Multiple regression analysis results for causal relationship between performance improvement constructs and lean constructs

Outcome Variables ⟹	Model 1		Model 2	
	Operational Improvements (OP_IMP)		Quality improvements (QTY_IMP)	
Input variables	**β**	**Sig. (p)**	**β**	**Sig. (p)**
Factor 1 (LP1)	0.173*	0.012	0.666*	0.000
Factor 2 (LP2)	0.220*	0.002	-	-
Factor 3 (LP3)	0.752*	0.000	0.345*	0.000
Factor 4 (LP4)	0.261*	0.000	0.211*	0.008
Durbin – Watson statistics	2.040		2.07	
Multiple R^2	*0.713*		*0.607*	
Adjusted R^2	*0.695*		*0.589*	
F statistics	*39.070*		*20.931*	
P value of F	*0.000*		*0.000*	
P value of model	0.000		0.000	

Note: * = significant at $p<0.05$ β = regression coefficients
Only significant relationship is illustrated

For each model, the value of the Durbin-Watson statistic is almost two, implying that the residuals are uncorrelated for all models. In model 1, significant predictor variables are LP1 (0.713, 0.012), LP2 (0.220, 0.002), LP3 (0.752, 0.000) and LP4 (0.261, 0.000). Positive coefficients suggest a positive relationship between lean practices comprising of quality management, supplier-related practices, visual control, SPC, work standardization, JIT purchasing, quick changeover, setup reduction, TPM, 5S, new equipment and technology, cross-functional teams and continuous improvements, and operational performance. As the extent of the implementation of these lean practices increases, operational performance also increases. The value of adjusted R^2 is 0.695. Therefore, it can be deemed that the implementation of quality management practices, flow, employee involvement practices and waste elimination practices account for almost 70% variation in the operational performance.

Regression model 2 fits well ($p<0.000$). Significant predictor variables are quality management (0.666, 0.012), waste elimination (0.345, 0.000) and employee involvement (0.211, 0.008). The value of adjusted R^2 is 0.589; therefore, it can be deemed that the implementation of quality management practices, waste elimination practices, and employee involvement practices account for almost 58.9% variation in quality improvement.

5. Discussion and Implications

The objective of this study was to investigate the impact of lean practices on performance in Indian process industries. The results verified that lean constructs, namely, LP1, LP2, LP3, and LP4 positively impacted operational performance and quality improvement. Therefore, it can be concluded that the implementation of lean practices is likely to make a significant positive contribution to the performance of Indian process industries. These results are in line with findings of previous studies (Lyons *et al.* 2013; Panwar, Jain, and Rathore 2015b). Our findings reveal that the adoption of lean practices can help Indian process industries with waste elimination, reduction of defects, timely deliveries, productivity, cost reduction and demand management.

The examination of individual factors in the model provides insights into which lean practices affect process industries' operational performance. For example, Model 1 illustrates that lean construct LP3 comprising of TPM, 5S and SPC has a maximum impact on operational performance. This makes good sense as process industries make use of equipment types such as compressors, pumps, evaporators, heat exchangers, valves and long pipes. Therefore, process industry operations are vulnerable to frequent breakdowns due to leakage and other maintenance issues. Successful implementation of TPM and 5S considerably reduces breakdowns and unavailability of equipment and aids in the reduction of process interruptions which can lead to high maintenance costs, piling up of materials at different stages and late delivery. Indian process industries struggle with high energy consumption and a high rate of accidents. It was observed that extensive use of TPM helped reduce energy consumption, reduce accidents, and improve employees' safety. The reason is that TPM is considered as a highly important tool in process industries not only to support the running of equipment continuously but also due to its effectiveness in the reduction of wastes in the form of equipment losses such as rejects, leakages and high maintenance costs. Kumar *et. al.* (2006) also found that the adoption of lean practices resulted in reductions in machine downtime, level of inventories and a reduction in accidents.

Lean factors LP1, LP2 and LP4 also have a positive association with operational performance measures. However, LP1 has a somewhat low impact on performance. This can be explained by recognizing that LP1 is comprised of external lean practices such as those pertaining to supplier relationships. Indian process industries are yet to mature with their lean implementation efforts particularly across the supply chains. That being noted, a significant positive association of LP1 and operational performance in Indian process industries can be explained by the fact that supplier-related lean practices help reduce shortages of raw materials, auxiliary materials or packaging materials thereby improving the level of productivity.

Regression model 2 between quality improvement and lean practices demonstrates that the adoption of quality management practices, employee involvement practices, and waste elimination practices provides an improvement in quality levels. It was observed that LP1 impacts quality improvement the most. LP3 also significantly affect product quality in Indian process industries. More importantly, since poor quality practices can result in rejections of entire lots in process industries, such problems need to be sorted out effectively with the adoption of quality control programmes. The implementation of a quality management programme such as total quality management and other quality initiatives also facilitate quality conformance thereby reducing reworks and rejects.

Major processes are typically carried out at a particular temperature and for a pre-defined time in process industries. Therefore, product quality highly depends on the process settings and parameters. Any variation in these settings can lead to the deterioration in quality. In such a scenario, visual controls and SPC play a vital role to check process variations and inefficient running of equipment. Visual controls help to control the contingency factors related to variations in quality and yield. SPC helps to minimize process variations. Furthermore, the overall quality of a product highly depends on the quality of raw materials. Variations in the yield and quality of raw materials can be reduced through supplier integration and long-term contracts with suppliers. Gebauer, Kickuth, and Friedli (2009) also claim that supplier-related lean practices have an influential effect on quality in process industries.

However, LP2, comprising of lot-size reduction, quick changeover, JIT purchasing and bottleneck removal, does not have a significant impact on quality performance. These practices are primarily related to flow and therefore did not influence the defect levels or rejects. Surprisingly, LP5, including pull production and production scheduling provide weak evidence of impacting both operational performance and quality improvement. This is understandable as, with large-capacity inflexible equipment, low product variety and the need for high capacity utilization, pull production is often not feasible in process industries. Less applicability of LP5 practices affirms the findings of Shah and Ward (2003) that process industries adopt these practices to a limited extent due to their lesser impact on capacity utilization. Secondly, sophisticated production scheduling is also not required due to low product variety in process industries. The non-significant impact of LP5 practices on performance upholds the findings that pull production and production scheduling have less applicability in process industries. Less applicability of pull systems and production scheduling supports the previous findings of Chavez et al. (2013) that the applicability of lean practices depends on the type of production system.

It is important to note that although the present study found that operational performance and quality improvement are positively related to the adoption of lean practices, the regression models show that the lean variables (or practices) considered in these studies only explained 70% or less variability present in the model. It means that there also exist some other controlling factors that influence operational performance. The possible explanations to this could be as follows:

In the present research, the effect of the level of employees' skill was not considered. For successful implementation of lean practices, an elevation in employees' skill is expected. It is likely that the Indian process industries under study lacked appropriate skills and expertise required for the efficient implementation of lean practices. For example, the majority of the respondents have a large number of contractual employees. Management typically does not arrange for rigorous training and education for the skill development of contractual employees. Therefore, such employees may find it difficult to follow the improvement procedures and methodologies as required, either due to low understanding or due to ignorance. Therefore, the adoption of lean practices results in a less-than-feasible level of performance improvement.

Furthermore, the regression models developed in this study are independent of firm size. It is likely to be difficult for the small process industries to implement lean practices extensively and thus, they can achieve only a limited improvement in performance. Therefore this study supports the findings of Dora, Kumar and Gellynck (2016) that the adoption of lean manufacturing in small process industries is challenging due to their distinct characteristics.

4.1 Theoretical Implications

Prior studies have advocated the positive impact of lean practices on performance. A few examples include: Fullerton, McWatters, and Fawson (2003), Nawanir, Teong, and Othman (2013), and Khanchanapong *et al.*(2014). However, their area of focus was discrete manufacturing. This study helps narrow the knowledge gap with regard to the impact of lean factors on operational performance in process industries, particularly in Indian process industries. On the other hand, the results of this study are aligned with similar prior studies on the implementation of lean in process industries (Upadhye Deshmukh and Garg 2010; Gupta, Acharya and Patwardhan 2013; Lyons et al., 2013) which demonstrate the authenticity of the findings of this study. Similarly, this research also confirms the transferability of lean to a process industry environment as claimed by Manfredsson (2016).

This study contributes to the lean literature by supporting the argument that whenever lean is applied in a new environment it is to be modified at operational as well as a strategic level to suit the requirements of the new environment in terms of lean tools and lean bundles. Therefore, this study confirms the claim that lean is dynamic in nature (Holweg et al. ,2007). This study is also in agreement with Bamford et al. (2015) in that it is not necessary that all lean tools should be applied to achieve improvements. It is true that even using the lean philosophy partially within certain operating constraints can result in dramatic outcomes with respect to operational performance. This study confirms the suggestion by Chavez *et al.* (2013) that the extent of the impact of lean practices is contingent on the type of production system.

Lean practices such as 5S, continuous improvement, work standardization, new equipment and technology, TPM and SPC have significant impacts on performance in process industries. Studies of Shah and Ward (2003) and Bortolotti et al (2015) had similar outcomes for other types of industries. Therefore, this study suggests that a few lean practices have similar impacts on performance improvement irrespective of the type of industries. Bortolotti et al (2015) describe these as the bundle of general lean practices which develop fitness of a firm so that further typical lean practices can be implemented according to the characteristics of the firm. The lean factors LP3 and LP4 identified in this study can be termed as 'fitness bundles'. These lean bundles impact both operational and quality performance and therefore have universal application in industries irrespective of their characteristics.

LP1 has less impact on operational performance and LP2 has less impact on quality performance which signifies that these practices have more impact on a particular type of performance. LP1 comprises of mainly external lean practices. The higher impact of LP1 practices on quality performance also suggests that although external lean practices may not impact all the aspects of performance, their use should not be ignored. Thus, this study advocates the findings of Hofer, Eroglu, and Hofer, (2012) that both internal as well as external lean practices cumulatively impact an organization's performance.

Notably, LP4 practices have considerable impact on both operational and quality performance in Indian process industries. LP4 consists of lean practices such as work standardization, flexible and cross-functional teams, new equipment and technology, and continuous improvement programmes. The impact of these practices is highly related to employee's involvement and cultural characteristics. It seems that the national culture of Indian process industries supports the implementation of LP4 practices. High ‘power-distance’, group collectivism and respect for authority and expertise, which characterize Indian national and industrial culture, suggest that imparting training becomes more effective and easy resulting in efficient and flexible cross-functional teams, and help increase the impact of lean practices such as continuous improvements and work standardization in performance improvement.

4.2 Managerial Implications

From the practitioner's perspective, this research helps with quantifying the change in operational performance through the adoption of lean practices in process industries. The findings of this study help establish a benchmark for the Indian process industry managers on which the transformation to a lean system can be effectively planned. On the basis of this study, the Indian process industry managers will be able to focus on those areas of performance where lean can be most effective and will be able to justify the adoption of corresponding lean practices. More specifically, managers can learn the following lessons from this study with respect to the implementation of lean practices in Indian process industres:

- The adoption of lean practices positively impacts the performance of a process industry in terms of both quality and operational performance.
- The higher the adoption of lean practices, the better control over inventory, waste minimization, timely deliveries, demand management, cost reduction and productivity.
- TPM, 5S and SPC have a significant impact on operational performance.
- LP1, comprising external lean practices such as supplier integration and development, has a lesser impact on operational performance in comparison to that of LP2 and LP4. Therefore, efforts should be made to increase the effectiveness of LP1. On the other hand, the impact of LP1 can further be increased in Indian process industries by adopting supplier development programmes.
- The adoption of lean practices in process industries also provides better control over first pass yield and quality. However, the adoption of supplier-related practices is also very important for improvements in quality performance.
- Pull production and production scheduling do not have a significant impact on performance in process industries, at least in the context of Indian process industries.

5. Conclusions and Future Work

The results of this study confirm that the adoption of lean practices has a significant effect on operational performance such as inventory management, timely deliveries, waste reduction, demand management, cost reduction and productivity improvement. More importantly, the findings of this research are in agreement with previous studies that the adoption of lean practices in process industry results in improvements in operational performance. Therefore, this study removes any ambiguity concerning the value of lean in the process industry sector even in an emerging economy such as India.

On the other hand, for the given sample, it was observed that the relationship between some lean practices (particularly pull systems) and performance improvement was weak. It can be attributed to understanding that the applicability of such lean practices comprising pull production and production levelling is very low in process industries. Therefore, this study suggests that the implementation of lean practices in process industries can be helpful mainly for the reduction of wastes and costs, and improvement of demand management and productivity.

A few shortcomings of this study should also be considered. Apart from the type of production system, the relationship of performance improvement to lean practices also depends on contextual factors such as size, unionization, and plant age (Shah and Ward 2003). For instance, small and medium enterprises (SMEs) have distinct characteristics compared to large firms (Sharma and Bhagwat 2006). Examples of such characteristics include a lack of supply chain power, fewer financial resources, and inadequately trained and semi-skilled employees. However, small firms can also have greater flexibility due to simpler internal organizational structures. Therefore, challenges to implement lean are different in different types and sizes of process industry, so the resultant benefits may also vary accordingly. Additionally, whenever a new business strategy is planned in a new sector or a new geographical area, a prominent challenge is to deal with resistance to change (Acosta et al. 2004). Therefore, further studies are required to interpret the relationship between the extent of the use of lean practices and performance improvement in process industries within the constraints of size, unionization, age and cultural aspects of process industries.

Lastly, the lean implementation models developed for discrete industries are not suitable for process industries where the process, product, supply chain and market characteristics are significantly different from discrete repetitive manufacturing. The literature on lean implementation frameworks in process industries is shallow compared to its discrete manufacturing industry counterpart. Therefore, further research is required to develop a comprehensive lean implementation framework for process industries.

References

Laosirihongthong, T., and G.S. Dangayach. 2005.“A comparative study of implementation of manufacturing strategies in Thai and Indian automotive manufacturing companies.”*Journal of manufacturing systems* 24(2):131-143.

Abdallah, A. B., and Y. Matsui. 2007. “JIT and TPM: their relationship and impact on JIT and competitive performances.” Paper presented at the Asia-Pacific decision science institute conference, Bangkok.

Abdulmalek, F.A., and J. Rajgopal.2007. “Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study.” *International Journal of Production Economics*107(1):223-236.

Acosta, C., Leon, V. J., Conrad, C., Gonzalez, R., and C. O. Malave. 2004. “Case study on culture and the implementation of manufacturing strategy in Mexico.”*Journal of manufacturing systems*23(3):204-214.

Aggarwal, A. 2002. “Liberalisation, multinational enterprises and export performance: evidence from Indian manufacturing.” *Journal of Development Studies*38(3):119-137.

Armstrong, J. S., and T. S. Overton.1977. “Estimating non-response bias in mail surveys. *Journal of marketing research* 1:396-402.

Bamford, D., Forrester, P., Dehe, B., and R. G. Leese.2015. “Partial and iterative Lean implementation: two case studies.” *International Journal of Operations & Production Management* 35(5):702-727.

Bevilacqua, M., Ciarapica, F. E., and C. Paciarotti. 2015. “Implementing lean information management: the case study of an automotive company.” *Production Planning & Control* 26(10): 753-768.

Billesbach, J.T. 1994. “Applying lean production principles to a process facility.”*Production and Inventory Management Journal*35(3):40-44.

Cagliano, R., Caniato, F., Golini, R., Longoni, A. and Micelotta, E. 2011. "The impact of country culture on the adoption of new forms of work organization". *International Journal of Operations & Production Management*, *31*(3):297-323.

Chavez, R., Gimenez, C., Fynes, B., Wiengarten, F., andW. Yu. 2013. “Internal lean practices and operational performance: The contingency perspective of industry clockspeed.” *International Journal of Operations & Production Management 33*(5): 562-588.

Cogdill, R. P., Knight, T. P., Anderson,C. A. and J. K. Drennen III. 2007. "The financial returns on investments in process analytical technology and lean manufacturing: benchmarks and case study." *Journal of Pharmaceutical Innovation* 2(1-2): 38-50.

Cortina, J. M. 1993. “What is coefficient alpha? An examination of theory and applications.”*Journal of applied psychology* 78(1): 98.

Costa, L.B.M. and Godinho Filho, M. 2016. "Lean healthcare: review, classification and analysis of literature". *Production Planning & Control*, *27*(10):823-836.

Danese, P., Romano, P., andT. Bortolotti. 2012.“JIT production, JIT supply and performance: investigating the moderating effects.” *Industrial Management & Data Systems*112(3):441-465.

de Waal, A. and Kourtit, K., 2013. “Performance measurement and management in practice: Advantages, disadvantages and reasons for use.” *International Journal of Productivity and Performance Management 62*(5): 446-473

Dey, P. K., and Walid C. 2013. "Green supply chain performance measurement using the analytic hierarchy process: a comparative analysis of manufacturing organisations." *Production Planning & Control,* 24(8-9): 702-720.

Dogra, M., Sharma, V.S., Sachdeva, A., and J.S. Dureja. 2011. “TPM-a key strategy for productivity improvement in process industry.” *Journal of Engineering Science and Technology* 6(1):1-6.

Dong, Y., Carter, C. R., and M E. Dresner.2001. “JIT purchasing and performance: an exploratory analysis of buyer and supplier perspectives.”*Journal of Operations Management*19(4):471-483.

Doolen, T. L., and M. E. Hacker.2005. “A review of lean assessment in organizations: an exploratory study of lean practices by electronics manufacturers.”*Journal of Manufacturing systems* 24(1):55-67.

Dora, M., Kumar, M. and X. Gellynck2016. “Determinants and barriers to lean implementation in food-processing SMEs–a multiple case analysis.” *Production Planning & Control27*(1): 1-23

Field, A. 2009. *Discovering statistics using SPSS.* London: Sage publications.

Flynn, B. B., Schroeder, R. G, and S. Sakakibara.1994. “A framework for quality management research and an associated measurement instrument.”*Journal of Operations management*11(4):339-366.

Fullerton, R. R., McWatters, C. S., and C. Fawson. 2003. “An examination of the relationships between JIT and financial performance.”*Journal of Operations Management*21(4):383-404.

Fullerton, R. R., and C. S. McWatters. 2001. “The production performance benefits from JIT implementation.”*Journal of Operations Management*19(1):81-96.

Garengo, P., and Sharma, M. K. (2014). Performance measurement system contingency factors: a cross analysis of Italian and Indian SMEs. *Production Planning & Control*, *25*(3), 220-240.

Gebauer, H., Kickuth, M., and F. Friedli.2009. “Lean management practices in the pharmaceutical industry.”*International Journal of Services & Operations Management* 5(4):463-481.

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

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

Hair, J. F., Anderson, R. E., and R. L. Tatham.1984. *Multivariate data analysis: with readings*. New York: Macmillan.

Hofer, C., Eroglu, C., and R. A. Hofer.2012.“The effect of lean production on financial performance: The mediating role of inventory leanness.”*International Journal of Production Economics*138(2):242-253.

Hokoma, R.A., Khan, M.K., and K. Hussain. 2008. “Investigation into the implementation stages of manufacturing and quality techniques and philosophies within the Libyan cement industry.” *Journal of Manufacturing Technology Management* 19(7):893-907.

Hokoma, R.A., Khan, M.K., and K. Hussain. 2010. “The present status of quality and manufacturing management techniques and philosophies within the Libyan iron and steel industry.” The *TQM Journal* 22(2):209-221.

Jaiganesh, V., and J.C. Sudhahar.2013. “Sketching out the hidden lean management principles in the pharmaceutical manufacturing.”*International Journal of Scientific and Research Publications*3(2):1-2.

Jimenez, E., Tejeda, A., Perez, M., Blanco, J., and E. Martinez.2012. “Applicability of lean production with VSM to the Rioja wine sector.” *International Journal of Production Research*50(7):1890-1904.

Jones, D., and J. Womack.2002. *Seeing the whole: mapping the extended value stream*.The Lean Enterprise Institute, Brookline, MA.

Karim, A. and K. Arif-Uz-Zaman. 2013. “A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations.” *Business Process Management Journal*. *19*(1):169-196.

Khanchanapong, T., Prajogo, D., Sohal, A.S., Cooper, B.K., Yeung, A.C.L., and T. C. E. Cheng. 2014. "The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance." *International Journal of Production Economics* 153: 191-203

Kim, J. O., and C. W. Mueller.1978. *Factor analysis: Statistical methods and practical issues.* London: Sage publications.

Koufteros, X., Verghese, A.J. and Lucianetti, L., 2014. The effect of performance measurement systems on firm performance: A cross-sectional and a longitudinal study. *Journal of Operations Management*, *32*(6), pp.313-336

Kull, T.J., Yan, T., Liu, Z. and Wacker, J.G. 2014. "The moderation of lean manufacturing effectiveness by dimensions of national culture: testing practice-culture congruence hypotheses". *International Journal of Production Economics*, 153:1-12.

Laureani, A., and Antony, J., 2010. “Reducing employees' turnover in transactional services: a Lean Six Sigma case study”. *International Journal of Productivity and Performance Management 59*(7):688-700.

Losonci, D., and K. Demeter.2013. “Lean production and business performance: international empirical results.” *Competitiveness Review*23(3):218-233.

Lyonnet, B., and R. Toscano.2014. “Towards an adapted lean system–a push-pull manufacturing strategy.” *Production Planning & Control*25(4):346-354.

Lyons, A. C., Vidamour, K., Jain, R., and M. Sutherland.2013.“Developing an understanding of lean thinking in process industries.” *Production Planning & Control*24(6):475-494.

Malhotra, N. K. 2006.*Questionnaire design and scale development*.California: Sage Publications.

Manfredsson, P. 2016. “Textile management enabled by lean thinking: a case study of textile SMEs.” *Production Planning & Control*: 1-9.

Mathur, A., Mittal, M.L., and G.S. Dangayach.2012. “Improving productivity in Indian SMEs.” *Production Planning & Control 23*(10-11): 754-768.

Melton, T. 2005. “The benefits of lean manufacturing: what lean thinking has to offer the process industries.” *Chemical Engineering Research and Design* A6: 662–673.

Miller, G., Pawloski, J., and C. R. Standridge.2010. "A case study of lean, sustainable manufacturing." *Journal of industrial engineering and management* 3(1): 11-32.

Miller, L. E., and K. L. Smith.1983. “Handling nonresponse issues.” *Journal of extension*21(5):45-50.

Moreira, C. A. and C. S Pais, G., 2011. “Single minute exchange of die: a case study implementation.” *Journal of Technology Management &Innovation 6*(1):129-146.

Nawanir, G., Teong, L. K., and N.S. Othman. 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.

Neely, A., Gregory, M., and K. Platts.2005. “Performance measurement system design: A literature review and research agenda.” *International Journal of Operations & Production Management 25*(12): 1228-1263.

Negrão, L.L.L., Godinho Filho, M. and Marodin, G., 2017. Lean practices and their effect on performance: a literature review. *Production Planning & Control*, *28*(1), pp.33-56

Nunnally, J. C. 1982. *Reliability of measurement*. *Encyclopedia of educational research.*New York: Free press.

Pandey, V. C., Garg, S. K., and R. Shankar.2010. “Impact of information sharing on competitive strength of Indian manufacturing enterprises- an empirical study.”*Business Process Management*16(2):226-243.

Panizzolo, R., Garengo, P., Sharma., M.K., and A. Gore. 2012. “Lean manufacturing in developing countries: evidence from Indian SMEs.” *Production Planning & Control*23(10-11):769-788.

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

Panwar, A., Jain, R., andA.P.S. Rathore. 2015a. “A survey on the adoption of lean practices in the process sector of India with a comparison between continuous and batch process industries.” *International Journal of Manufacturing Technology and Management 29*(5-6): 381-401.

Panwar, A., Nepal, B.P., Jain, R., and A.P.S. Rathore. 2015. “On the adoption of lean manufacturing principles in process industries.”*Production Planning & Control*26(7):564-587.

Piercy, N., and N. Rich. 2009. “Lean transformation in the pure service environment: the case of the call service centre.” *International Journal of Operations & Production Management* 29(1):54-76.

Piercy, N., and N. Rich.2015. “The relationship between lean operations and sustainable operations.” *International Journal of Operations & Production Management*35(2):282-315.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.Y., and N. P. Podsakoff. 2003. “Common method biases in behavioral research: a critical review of the literature and recommended remedies.” *Journal of applied psychology* 88(5): 879.

Poongothai, S., and R.I.L.K.S. Arul.2011. "Total quality management: the path for continuous quality enhancement in pharmaceutical sector."*Asian Journal of Biochemical and Pharmaceutical Research* 1(2): 321-328.

Radnor, Z., and R. Johnston.2013. "Lean in UK Government: internal efficiency or customer service?" *Production Planning & Control*24(10-11):903-915.

Rao, P.(2013). "The role of national culture on "best" practices in India: a multiple case study approach." *Journal of Indian Business Research,* 5(2):122-143.

Roy, R.N., and K.K. Guin. 1999."A proposed model of JIT purchasing in an integrated steel plant."*International Journal of Production Economics*59(1):179-187.

Santos, J. R. A. 1999. "Cronbach's alpha: A tool for assessing the reliability of scales."*Journal of extension*37(2):1-5.

Shah, R., andP.T. Ward.2003. "Lean manufacturing: context, practices bundles, and performance." *Journal of Operations Management*21(2):129-149.

Sharma, M.K., and R. Bhagwat. 2006. "Practice of information systems: Evidence from select Indian SMEs." *Journal of Manufacturing Technology Management*17(2):199–223.

Small, M.H., Yasin, M.M., and J. Alvi. 2011. "Assessing the implementation and effectiveness of process management initiatives at technologically consistent firms." *Business Process Management Journal,* 17(1):6-20.

Susilawati, A., Tan, J., Bell, D., and M. Sarwar. 2015. "Fuzzy logic based method to measure degree of lean activity in manufacturing industry." *Journal of Manufacturing Systems* 34:1-11.

Taylor, D.H. 2006. "Demand management in agri-food supply chains: an analysis of the characteristics and problems and a framework for improvement." *International Journal of Logistics Management* 17(2):163-186.

Upadhye.N., Deshmukh, S.G., and S. Garg. 2010. "Lean manufacturing in biscuit manufacturing plant: a case." *International Journal of Advanced Operations Management* 2(1-2):108-139.

Upasani, S. 2012. "Emerging supply chain management practices in Indian manufacturing industries." *International Journal of Research in IT & Management*2(2):1237-1248.

Villarreal, B., Garza-Reyes, J.A. and Kumar, V. 2016. "Lean road transportation–a systematic method for the improvement of road transport operations". *Production Planning & Control*, *27*(11):865-877.

Vlachos, I. 2015. "Applying lean thinking in the food supply chains: a case study". *Production Planning & Control*, *26*(16):1351-1367.

Wesseling, J.H., Lechtenböhmer, S., Åhman, M., Nilsson, L.J., Worrell, E. and Coenen, L., 2017. The transition of energy intensive processing industries towards deep decarbonization: characteristics and implications for future research. *Renewable and Sustainable Energy Reviews*, *79*, pp.1303-1313

Womack, J. P., and D. T. Jones. 2002."From Lean Production to Lean Enterprise." *Managing Innovation and Change* : 138.

Womack, J.P., and D. T. Jones. 1996. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. New York: Simon and Schuster.

Yang, T., Kuo, Y., Su, C. T., andC.L. Hou. 2015. "Lean production system design for fishing net manufacturing using lean principles and simulation optimization." *Journal of Manufacturing Systems 34:* 66-73.