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Understanding the linkages between lean practices and performance improvements in Indian process industries

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1. Introduction

The adoption of lean production has helped the manufacturing industry to successfully withstand intense competition (Womack and Jones, 1996). According to White *et al.* (1999), *lean* results in improvement of lead times, quality levels, labor productivity, inventory levels, and manufacturing costs. As a result, lean production has proven highly successful in elevating overall performance of manufacturing organizations (Panizzolo *et al.,* 2012; Vinodh and Joy, 2012).

In a survey of Australian manufacturing companies, Sohal and Egglestone (1994) found that the lean adopters were able to reduce wastes, costs, inventory levels, reworking, and quality problems. Fullerton *et al.* (2003) describe that adoption of just-in-time practices positively contributes to a firm's profitability. In a recent study of 187 Thai manufacturing plants, Rahman *et al.* (2010) found that implementation of *lean* could be beneficial in improving such performance metrics as quick delivery, unit cost, productivity, and customer satisfaction.

While there is no dispute over the application of lean practices in discrete industries, there are some mixed thoughts among the prior researchers on the same about process industry. For example, Melton (2005) and Shah (2005) suggest that process industries could also benefit from lean implementation. Melton (2005) argues that all the seven wastes according to lean philosophy also exist in process industries. According to the paper, process industries accrue waste like 'over-production' due to continuous large scale manufacturing. In process industries large quantity of work-in-process is subjected to significant 'wait-time' due to sequential processing, lab tests, and paperwork. 'Inventory' levels are also high in process industries due to large buffer stocks and large warehousing. Similarly, process industries have non-value added activities in the form of unnecessary transportation, unnecessary motion, over-processing and defects. On the other hand, other researchers argue that *lean* is suitable only for discrete manufacturing (Jorgensen and Emmitt, 2008; Pattersen, 2009). Discrete manufacturing firms are those in which the product is in form of countable and separable units, such as automobile and electronics industries. Based on these articles, it can be summarized that although principally speaking lean is also beneficial for process industries (Melton, 2005), it is difficult to adopt lean at operational level due to unique process characteristics of process industries (Pattersen, 2009). Furthermore, publications related to lean adoption in process industries are fewer compared to those on discrete manufacturing which might have added to skepticism about *lean's* usefulness in process industries (Gebauer *et al.,* 2009).

In addition, our review of existing lean manufacturing literature reveals that much of prior works on lean is focused on companies from the developed countries like Europe or North America (e.g., Cox and Chicksand, 2005; Lyons et al., 2014; Jasti and Kodali, 2015); very few of them are from developing countries like India. Vinodh and Joy (2012) conducted a study on lean manufacturing practices of 60 small and medium size manufacturing companies from South India. The authors found that management's role and strategies were the key drivers for successful implementation of lean. Furthermore, majority of research in lean is case driven, meaning that implications may be somewhat limited as compared to those of a comprehensive survey-based research. For example, based on their case studies of four Indian manufacturing companies, Panizzolo et al. (2012) suggest that implementation of lean manufacturing principles improved the operational metrics of all of the four companies. Similarly, Tanco et al. (2013) present a case study of South American food manufacturing company on application of lean analysis tools like value stream mapping for identifying and eliminating the waste. More importantly, majority of prior studies (including the ones mentioned above) are concentrated on discrete manufacturing environment (Bhamu and Sangwan, 2014) and very few of them are on process industries. Some of the recent lean studies on process industry environment include Lyons et al. (2013) Dora and Gellynck (2015). While Lyons et al. (2013) describe that lean practices have been applied throughout the different types of process industries in UK, their study did not examine the impact of lean on specific performance metrics such as inventory levels, delivery lead time, etc. On the other hand, Dora and Gellynck (2015) observed that there was lack of a structured approach in implementation of lean in food processing industries even in Europe, especially at the small and medium sized companies. As for developing countries like India, a recent study by Panwar et al. (2015b) found that the adoption of lean was very limited in Indian process industry.

In summary, our review of prior works on implementation of *lean* in process industry reveals that this stream of literature is still evolving, therefore, there are many unanswered research questions such as the impact of *lean* on specific performance metrics. More specifically, while there are ample studies on lean manufacturing in Indian industry, the existing literature is very shallow with respect to adoption of lean manufacturing practices in Indian process industries.

Therefore, the objective of this paper is to investigate if there is any statistically significant evidence about the impact of lean practices on the performance of process industries in India. The study consists of a survey of 121 Indian process manufacturing companies from multiple industry sectors including both adopters and non-adopters of lean practices. While Panwar et al. (2015b) provides an overall status of lean adoption in Indian process industry, this paper provides much deeper insights on implementation of lean in Indian process industry by examining the impact of lean on such specific performance metrics as *level of waste, productivity, defects rate, first pass yield, manufacturing cost, inventory levels, lot size, space utilization,* and *on-time delivery*. Furthermore, in order to validate the findings of the survey and generate more industry insights, we also present two case studies on Indian process industry. Lastly, implications for academic and industry practitioner are also discussed in the paper based on the results of the survey and as well as of the case studies.

2. Related Literature and Formulation of Research Hypotheses

Lean manufacturing principles have been in practice for a long time so there is an ample literature on lean especially in the discrete manufacturing domain. However, the objective this section is not to provide an exhaustive review of the overall lean literature. It is rather focused on identifying the prior works on the application of lean in process industries and how it has resulted (if any) in improvement of their performance. Thus the findings of the literature review essentially form the basis for our hypothesis formulation.

2.1 Performance Improvement through Lean and Characteristics of Process Industry

Shah and Ward (2003) describe 22 lean practices as the elements of lean manufacturing. Important lean practices that have appeared the most in literature 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, TQM (total quality management), HRM (human resource management) and JIT (just in time) and mixed model production (Fullerton, 2003; Taj and Morosan, 201,Shah and Ward, 2003).

Unlike those products representing discrete industries, the final products of process industries are practically inseparable units. Because of the 'continuous flow,' of manufactured goods, process industries have low work-in-process, consistent output chemistry, and long setups with large batches. They are also less responsive to change and have single routing and simple scheduling (Fransoo and Rutten, 1994; Partovi, 2007). Batch process industries are characterized by high work-in-process, variable output chemistry, fast set-ups, and small batch production (Houghton and Portougal, 1995). Process industries also have expensive specialized equipment, strict environmental considerations, and a high degree of automation (Ashayeri *et al.*, 1996). Hence, there is a strong focus on cost reduction and return on assets. Process industries are also subject to strict constraints on deterioration of raw material quality due to long storages and limited shelf lives (van der Vorst *et al.*, 2001).

2.2 Implementation of Lean in Process Industries

Adoption of lean manufacturing in industries having characteristics different from discrete industries is not straight forward (Sloan et al., 2015). Dora and Gellynck (2015) add that failure or success of lean in a sector different from discrete manufacturing highly depends on sector contextual factors. On the other hand, there are few researchers that have reported performance improvements in process industries due to implementation of lean. For instance, Cook and Rogowski (1996) and Abdulmalek and Rajgopal (2007) mention that adoption of *lean* can result in reduction in lead time, lead time variability, and accuracy in demand forecasting saving a huge amount of working capital. Furthermore, *lean* practices also help with increase in equipment availability, reduction in inventory, reduction in wastes, and improvement in quality (Upadhye *et al., 2010;* Jimenez *et al.*, 2011; Hodge et al., 2011).More recently, Panwar *et al.* (2015a) suggested that *lean* is effective in shop floor management of process industries in a similar fashion as in discrete manufacturing firms such as electronics or automobile.

2.3Research Gap and Hypotheses Development

Prior authors have questioned the suitability of *lean* adoption in process industries (Cox and Chiksand, 2005; von der Vorst, 2001). More specifically, lean manufacturing has been introduced in India only recently (Ghosh, 2012). According to Thanki and Thakkar (2014), awareness about lean in Indian industries is very limited. Level of implementation of lean manufacturing in Indian process industries is very low (Panwar et al, 2015b). Therefore, managers of Indian process industries need further explanations on performance improvement through adoption of lean manufacturing. Thus, in this study, we aim to explore whether *lean*, if adopted in Indian process industries, can actually bring about positive changes in performance or not.

Therefore, skepticism on the validity of *lean* in process industries and the lack of empirical studies to that end has helped us with the formulation of our hypotheses. Our hypotheses are focused on determining if there is any statistically significant impact of lean practices on specific performance metrics in Indian process industries as listed below.

H1: There exist significant differences between adopters and non-adopters of lean practices in Indian process industries with respect to:

a. level of waste,

b. productivity,

c. level of defects,

d. first-pass yield, and

e. manufacturing cost.

Our hypotheses are well grounded in the published literature as described below.

Abdulmalek and Rajgopal (2007) suggested that adoption of lean tools results in reduction of production lead time and lowers inventories in process industries. Koumanakos (2008) reported that process firms having a lean inventory management system demonstrated improvement in financial performance. Upadhye et al. (2010), Hodge et al. (2011), and Jimenez et al. (2011) argue that lean manufacturing helps process industries to elevate performance regarding reduction in lead time and inventory, increase in equipment availability, reduction in wastes, and improvement in quality. Lastly, Tanco *et al.* (2013) demonstrated that the adoption of *lean* in process industries resulted in performance improvement.

On the other hand, Bergrenn (1993) describes the difficulty of producing small batches in process industries. Shah and Ward (2003) found that JIT deliveries being less popular in process industry, which raises a question about inventory reduction. Likewise, Jain and Lyon (2009) and Lyon et al. (2013) suggest that aligning production with demand (e.g., pull system, cellular layout) are less popular in process industries, which will have a negative effect on timely deliveries, lot size reduction, and efficient space utilization, Similarly, Panwar *et al.* (2015b) found that the adoption of lean practices such as *Kanban*, pull production, production scheduling and cellular manufacturing is very limited in Indian process industries. This suggests that operational benefits such as inventory reduction, timely deliveries and lot size reduction, which are deemed to be associated with these lean practices, may not be visible in Indian process industries. Thus, our second set of hypotheses is as follows.

H2: There are no significant differences between adopters and non-adopters of lean practices in Indian process industries with respect to:

a. level of inventories,
b. small lot production,
c. space utilization, and
d. timely deliveries.

3. Research Methodology

In this research we used a comprehensive survey of Indian process manufacturing companies to test our hypothesis. Prior studies suggest that a survey methodology brings superior 'deductibility' over field methods and increases confidence in the generalizability of the results (Jick, 1983). Furthermore, Kraemer (1991) identified that the results synthesized from a survey are immensely improved if used in conjunction with a case study. Thus, grounding on the existing literature, in this research we adopted a survey based research followed by direct case studies. While the survey helped to test the proposed hypotheses, case studies facilitated not only validation of survey results but also provided deeper insights regarding performance improvement in process industries due to implementation of *lean*.

3.1 *Survey Instrument*

A structured questionnaire was used to collect survey data following the methodology adopted in earlier studies related to *lean* implementation (Lyons *et al.,* 2013; Shah and Ward, 2003). First, a draft questionnaire was prepared based on literature review regarding *lean* implementation and operational performance in the process industries. In the next stage, the draft questionnaire was modified for relevancy and ease of execution based on the feedbacks from subject matter experts including both academia and industry. Survey questions used in this study are furnished in Appendix I.

3.1.1 Measures of performance improvement

To investigate the level of various performance measures, as perceived by Indian process industries, a scale containing nine measures was developed, which was adapted from the works of Shah and Ward (2003) and Fullerton and McWatters (2001). The frequently mentioned performance measures in *lean* literature are summarized in Table 1. Respondents were asked to rate the operational performance on a five point Likert scale (Malhotra, 2006).The Likert scale ranged from 1= very low to 5= very high.

Table 1: Operational performance measures

Issue	No. of items	Items	Literature source	Cronbach's alpha
Operational performance measures	9	Wastes Number of defects Productivity Manufacturing costs First pass yield Level of inventories Timely deliveries Small lot production Space utilization	Fullerton and McWatters (2001) Shah and Ward (2003)	.861

In this study, a very high value of Cronbach's alpha (0.861) confirmed that the scale to measure operational performance is reliable and has high internal consistency (Nunnally, 1982).

3.1.2 *Measures of lean practices*

In a study for discrete industries, Fullerton and McWatters (2001) investigated effect of ten lean practices on performance through lean adoption. In their seminal work, Shah and Ward (2003) used 22 lean practices to study performance improvement through lean implementation. For Indian manufacturing firms, Ghosh (2012) proposed a set of seven lean practices to estimate performance improvement through the implementation of lean practices. For process industries, Lyons et al. (2013) examined application of twenty-three lean practices. However, a few lean practices are not applicable in process industry setup due to typical process characteristics (Panwar et al., 2015a). For examples, cellular manufacturing, focused factory and *Kanban* have got only a limited application in process industries due to its unique characteristics (Abdulmalek and Rajgopal, 2007, Jimenez et al., 2011). Based on these studies, eighteen lean practices were selected to explore performance improvement through adoption of lean practices in Indian process industries. A five-point Likert scale was developed to measure the extent of the use of lean practices. The Likert scale ranged from 1 = not implemented to 5 = complete implementation (See Appendix-I).

3.2 Administration of the Survey

For data collection, a sample of 500 Indian process manufacturing companies was selected randomly from a directory of ISO: 9001 certified process industries published on the website of *Indiacatlog.com*. This directory contains addresses of about 3000 Indian process industries including cement, chemical, pharmaceutical, food, paper, plastic, rubber and beverages manufacturing firms. The questionnaire was addressed to higher managers who were responsible for production. The invitation letters and surveys were mailed to possible participants by using the Indian postal service. Initially, the response rate was low in spite of two reminders. Hence, in an effort to increase response rate, a few responses were collected through face-to-face interviews. To increase the response rate further, two emails were sent, followed by one telephonic request for reply. In total, 121 responses were received, which is roughly 25%.Thiswas a good response rate for a typical large survey, especially in the context of India (Malhotra and Grover, 1998; Sahay *et al.*, 2006). For example, Ghosh (2012) achieved a response rate of 20% in a study of lean manufacturing implementation in Indian manufacturing companies.Ghosh's2012study was in context to the entire manufacturing sector of India, while our study was concentrated around a subsector (process sector) of the manufacturing industry. Similarly, Upasani (2012) and Pandey *et al.* (2010) reported a response rate of 17.5% and 18.02% respectively in similar studies.

According to Armstrong and Overton (1977), if the respondents and non-respondents differ significantly, then the results of the survey will not represent the whole population. Therefore, it is mandatory to confirm that the data do not have response bias. Armstrong and Overton (1977) describe that one method to avoid non response bias is to compare known values of the respondents and non-respondents. For this study, a non-response bias test based on annual sales was conducted between respondents (N=121) and non-respondents (N=374). Five firms which did not respond were excluded from the non-response test due to unavailability of annual sales figure. No noticeable differences among variables could be detected. Therefore, it was ascertained that a non-response bias did not exist.

3.3 Administration of the Case Studies

During survey administration, the respondents who had adopted lean practices were asked if they were willing to participate in further research. The respondents who agreed were checked according to selection criteria such as annual turnover, type of production, willingness to participate, agreeing to facilitate multiple plant visits, and permission to share relevant information. Eventually two case studies were confirmed: a refinery and a primary metal manufacturing plant.

Preliminary information on case companies was gathered through Internet search. In the next stage, personal visits to the case company plants were organized. During the site visit, several personal interviews were conducted with plant managers and other staff members. The interviewees were selected based on their rank (e.g., manager, general manager, managing director), department (e.g., productions, operations, performance improvement) and their subject knowledge on lean practices. Where applicable, documents pertaining to the implementation of improvement initiatives, operating procedures, sales data and plant layout were obtained from the observed sites.

At the outset of an interview, the first job was to briefly explain the motive of the research and simultaneously describe the lean manufacturing paradigm with associated lean practices. The interview was mainly focused on information regarding lean manufacturing implementation such as adoption of lean practices and performance assessment based on performance factors highlighted in the questionnaire. Interviewees included managing directors and production managers. There were nine interviews conducted between the two case study companies (i.e., five from Case 1 and four from Case 2). On an average, each interview lasted for two hours. After interviewing the managing directors who were also responsible for implementation of manufacturing and performance improvement strategies, a comprehensive visit of the shop floor, warehouses, and administrative offices was conducted for further observations along with study of relevant records. Thus each visit lasted for about 5 to 6 hours. To gather further information, or to clarify doubts, multiple visits were carried out at each plant. Finally, the observations were compiled on MS Excel and compared with the relevant findings from the survey research.

4. Survey Analysis

4.1Distribution of Respondents

It is evident from Table 2that the sample includes respondents from a wide spectrum of process industries such as cement (9.1%), food (22.3%), chemical (13.2%), pharmaceutical (5%), textile (1.7%), steel (17.4%) and petroleum (10.7%).Further, 78 (64.5%) respondents indicated that they were familiar with lean manufacturing, out of which 68 respondents (56%) replied that they used lean practices. Interestingly, 53 respondents (44%) had not adopted any lean practice.

Table 2: Distribution of survey respondents

Type of company	Number of respondents	Percentage
CEMENT	11	9.1
CERAMICS	4	3.3
CHEMICAL	16	13.2
FOOD AND DRINK	27	22.3
PHARMACEUTICAL	6	5.0
PLASTIC AND RUBBER	4	3.3
STEEL	21	17.4
TEXTILE	2	1.7
PETROLEUM	13	10.7
SUGAR	4	3.3
BEVERAGE	8	6.6
PAPER	4	3.3
OTHER	1	0.8
Total	121	100.0

4.2Hypothesis Testing and Results

In order to test the hypotheses proposed in this research, the respondents were segregated into *lean* adopters and non-adopters. The statistical package SPSS 20.0 was used for analysis. Considering the fact that the distribution of the individual operational performance measures is non-normal, a non-parametric test (Mann Whitney U-test for two samples) was used for statistical analysis of data. Table 3presents descriptive statistics of the mean ranks of variables tested in this study for *lean* adopters and non-adopters and the results of the Mann Whitney Utest.

Table 3: Results of two samples of Mann Whitney U test between adopters and non-adopters of lean practices.

Test Statistics		Level of wastes	Productivity	Level of defects	First pass yield	Manufacturing cost	Inventory levels	Lot size	Space utilization	Timely deliveries
Mean Rank	Adopters	77.61	69.85	71.63	76.73	80.18	74.59	64.63	50.82	64.87
	Non adopters	39.69	49.64	47.37	40.82	36.40	43.57	56.35	56.30	56.04
Mann-Whitney U		672.5	1200.0	1079.5	732.50	498.0	878.0	1555.5	1030.5	870.0
Z score		-6.058	-3.277	-3.990	-5.850	-7.130	-5.030	-1.339	-.886	-4.436
Significance(2-tailed)		**.000***	**.001***	**.000***	**.000***	**.000***	**.000***	**.181**	**.376**	**.001***
Test result		□□	□	□	□□	□□	□	x	x	□□

***Note*: * significant at 95% confidence level**
Lean adopters (n1) = 68Non-adopters (n2) = 53
□

It is evident from Table 3 that respondents reported a significant improvement in timely deliveries, level of wastes, level of various costs, level of inventories, first pass yield, level of defects, and productivity with the implementation of lean practices. However, statistical analyses provided weak evidence of the difference in performance with respect to lot size reduction and utilization of space.

4.2.1 Performance improvement through adoption of lean practices

A closer look of the data gathered in this study revealed that significant differences exist in the level of wastes between *lean* adopters and non-adopter process firms, which suggest that adoption of lean practices helps to improve performance. A brief analysis of the results has been provided in following paragraphs regarding the use of lean practices and their impact on performance metrics:

a. *Level of wastes: Lean* adopter firms showed significant reduction in wastes in comparison to non-adopter firms. *Lean* adopter firms have implemented 5S, TPM and visual control which facilitate uninterrupted working. Therefore, it helped them to reduce wastes generated from delays, unwanted buffers, piling up of inventories, and other hindrances in production. Furthermore, process industries have considerable losses due to leakages and the *lean* adopter firms have controlled such losses with the application of 5S, TPM and visual control.
b. *Level of defects*: The use of work standardization, SPC, mistake proofing, and visual control eliminate the chances of delays and rework from occurring, which resulted in reduction in defects. Furthermore, the implementation of supplier-related lean practices such as supplier development, supplier integration, and supplier rationalization can help guarantee the raw material quality there by reducing variations in raw material quality leading to fewer rejections and reworks while processing.
c. *First pass yield:* First pass yield depends heavily on process. A slight increase in process variations can result in large decrease in the first pass yield. Lean adopters show a noteworthy use of SPC, visual control, work standardization and quality management initiatives which probably resulted in control over contingency factors of variations in processes leading to higher first pass yield.
d. *Timely deliveries:* In process industries, timely supply of auxiliary materials (ingredients other than major raw materials) and packaging materials are of prime importance to avoid

shortages and to meet production schedules. As a result of supplier integration and supplierdevelopment policies, the interruption in production due to shortages of raw materials, auxiliary materials, or packaging materials have been reduced leading to improvement in the delivery schedules.

e. *Inventory levels*: In a few process industries among the respondents, JIT delivery was compulsory due to the perishable nature of the product. Lean adopter process industries showed higher usage of TPM, 5S techniques along with automation and advanced manufacturing technologies, facilitating higher rates of inventory turnover, faster processing and timely deliveries, and less human interference, thus reducing inventory levels bya significant margin.

f. *Manufacturing costs*: Maintenance costs are a large fraction of overall costs in process industries. Due to deployment of maintenance policies by adopting TPM and 5S, lean adopter firms enjoyed considerable decrease in maintenance costs. As stated earlier, energy consumption is reduced with the application of lean practices resulting in savings in energy costs in lean adopter process industries. Lean practices eventually help to meet quality requirements and thereby save considerable costs involved in rejections.

g. *Productivity:* As previously discussed, process industries are labor intensive and the adoption of *lean* helps in the release of labor-reducing costs. Additionally, process industries consume high amounts of energy because the processes are usually carried out at elevated temperatures and pressures. The adoption of lean practices helps in the efficient utilization of equipment and machinery. This, in turn, cuts energy requirements and improves the productivity.

5. Case Studies

5.1 Case 1: A Refinery

Case 1 represents one of the ten refineries of the largest commercial petroleum enterprise in India. This company was ranked under 100 in the Global Fortune 500 list for the year 2012. It had a turnover of USD 65 Billion with a net profit of USD 505 in 2012-13. This refinery was commissioned in 1982 as the company's sixth refinery with an original capacity of 6 million metric tonnes per annum (MMTPA), which was increased to 8 MMTPA through a revamp in July 2000.

Major products produced at the refinery are petroleum products, aviation fuel, propylene, furnace oil, and naphtha. The refining process is comprised of four basic steps: distillation, cracking, treating, and reforming. The plant is high volume and low variety with highly inflexible dedicated equipment, fixed routing, and continuous processing. The plant has espoused a quality management system standard ISO9001, environmental management system standard ISO14001, and occupational health & safety management system standard OHSAS18001.

5.1.1 Lean assessment

The goals of implementing lean practices were to reduce number of defects, abnormalities, breakdowns, losses, and accidents to zero level, and curb pollution. Standard operating procedures were being followed for all operations. Statistical process control was formally adopted to minimize the variations in processes. In December 2003, TPM was initiated in the refinery. TPM was not only termed as total productive maintenance but it was viewed as total productive management.

TPM was implemented with a view to eliminate all unnecessary cost associated with material, operations, maintenance time and minimization of all types of losses, with complete involvement of every employee. TPM, visual control, and 5S principles were being followed in every section of the refinery including office to increase productivity, reduce the number of sporadic failures and improve equipment efficiency and plant effectiveness.

The company had also setup a quality improvement program, in part, to satisfy the customer and also to meet the stringent regulatory requirements. It adopted quick changeover techniques owing to the fact that it is a refinery and after periodic shut downs, it takes significant time to restart high capacity, complex equipment.

In addition, a continuous improvement program was formally implemented in the refinery to make improvements in operation, energy conservation, and safety. The concept of flexible and cross-functional teams had also been widely implemented in the plant. This helped in operations and maintenance. The company invested considerably in new technologies and in the installation of new equipment for process modifications to reduce energy consumption. A continuous improvement program also helped in the generation of an idea bank in the refinery.

Kaizens growth rate increased 15 times after the implementation of lean practices.

5.1.2 Performance improvement

The plant reported several improvements in performance as the consequences of implementation of lean practices. Following paragraphs provide the summary of the improvements on various metrics.

a) *Level of wastes*: plant reported a considerable curb in wastes including losses due to leakages, breakdowns, improper maintenance, old technology, and equipment. Plant could cut the unnecessary movement of materials and workers to significant level after adoption of lean practices such as TPM, continuous improvements, standard operating procedures, 5S and visual control.

b) *Number of defects*: Relentless efforts for quality management significantly reduced the number of defects and customer complaints. For example, weighted quality rate of various products was improved by 10%. Reduction in number of complaints was almost y %. Moreover, reprocessing and rework were reported to be zero after the formal adoption of quality management programs.

c) *Productivity*: *Lean* initiatives had helped the plant to achieve an increase in productivity by 1.5% in financial year 2012-13 after the formal implementation of lean practices.

d) *Manufacturing costs*: Overall reduction in various costs was around 30%.Improvement efforts resulted in a savings of direct fuel consumption estimated at 3000 standard refinery fuel tons (SRFT)/year. The monetary savings were estimated to be about half million US dollars per year.

e) *First pass yield*: plant reported an increase in first pass yield after implementation of lean practices including SPC, visual control, supplier integration, work standardization, TPM and quality management practices.

f) *Level of inventories*: spare parts accounted for a considerable cost in the company. Maintaining spare parts inventory was critical from the cost perspective. Therefore, as part of TPM, the plant adopted a spare parts inventory management policy for economically effective inventory management.

g) *Timely deliveries*: employing lean practices resulted in timely availability of all inputs, intermediate and final products and goods and services to the highest satisfaction of internal and external customers. Delays reduced considerably

h) *Small lot production*: pull production was not visible in the plant. Managers reported that for efficient capacity utilization it is essential to run the plant at near full capacity. Since the plant offered only low product variety, and for each product, a separate production line existed, the plant did not employ production levelling. The managers argued that small lot production was not feasible in the plant because of continuous nature of production process.

i) *Space utilization*: different units in the plant were developed gradually and were commissioned over a wide span of time. The primary unit was common for all units. However, the distance between units was very large. This resulted in several losses and other problems. Maintenance was cumbersome due to these distances. Therefore, improper plant layout was visible in the plant.

Finally, due to continuous pursuance of excellence through the adoption of a wide spectrum of lean practices, the refinery has not only achieved milestones in performance but also has won many awards including ‘Oil Industry Safety Awards’ and ‘Second Best Performer Award’ for 2009-10 in the refinery category.

This case study provided some very interesting insights on potential adoption of *lean* practices in Indian process industry. Case 1 illustrated that a vast majority of lean practices can be implemented in a process industry. In-fact, as mentioned earlier, the company has implemented a wide number of lean practices, which resulted in performance improvements with respect to several metrics. The company also extended the implementation of lean practices beyond the shop floor to procurement, sales, and the other office works environment. Lastly, this case also demonstrated that *lean* can be successfully implemented in not just in the developed countries but also in the developing nations like India.

5.2 Case 2: Primary Metal Manufacturing Plant

This case study plant was a government-owned copper extraction plant. It was located in the state of Rajasthan, 180 km from Delhi. The plant started operations in 1975. The plant had a capacity of 31,000 tonnes per annum copper cathode. However, the smelter and acid plants had been shut down since late 2008. The reasons for the shutdown were the slump in global commodity prices witnessed in 2008 and the incumbent old machinery. At the time of the survey, only the refinery for the production of copper concentrate was working in addition to associated mines. The plant was producing 9,500 metric tonnes of metal in concentrate per annum.

The plant was characterized by a high level of raw material inventory since the extraction work in the mines was carried out round-the-clock. In addition, the plant sensed the importance of stocking a huge amount of raw material inventory for continuous processing which was important for economy of scale production and high capacity utilization. The plant was also characterized by a high finished goods inventory. The plant used a make-to-stock strategy. Most importantly, the plant had old equipment and outdated technology, which was not energy efficient. Thus, the plant was characterized by very high energy consumption. The plant was labor intensive due to low automation. Before 2008, the plant had more than 20,000 employees when all the units of the plant were in operation. However, after 2008 most of the units of the plant, including the smelter was shut down and, hence gradually, the employees were either retired or encouraged to take voluntarily retirements to reduce the financial burden on the plant.

5.2.1 Lean assessment

The plant had not initiated any performance improvement efforts. Consequently, it had to face severe losses. The plant had to compromise on quality of the product due to old equipment. Moreover, the units of the plant were located such that the WIP had to travel long distances for further processing.

The management did not pay serious attention towards skill development, training and education of the employees; therefore, mishandling of equipment, ignorance and improper operating was frequent in the plant. No visual techniques were used in the plant for efficient working. Although, the plant adopted a preventive maintenance strategy, it had to be revisited. According to existing maintenance policies, the milling units were shut down weekly for maintenance. At the time of the plant's scheduled weekly shut down, the WIP value was four million US dollars in the downstream equipment, which had to be discarded. 5S, a continuous improvement program, quality management program, SPC, work standardization and all other lean practices did not exist in the plant.

However, the plant managers reported that there was not any considerable performance improvement as there was no adoption of any lean practices.

5.2.2 Reasons for not implementing lean

The main obstacle for transition to lean practices was the existence of age old technology. However, due to heavy losses, the management was not planning to buy new technology. Another reason for not adopting lean practices was unfamiliarity with the *lean* concept. When we explained the meaning of *lean*, managers replied that small batch production was not feasible in their plant; hence, *lean* was not suitable for them. Old equipment, lack of training and a need for education of employees, and mainly lack of government policy to revitalize the plant were some reasons why the management was facing problems in its quest to run the plant efficiently.

5.3 Cross Case Comparison

It was observed that Case 1 adopted lean practices formally and extensively; however, Case 2 did not implement lean practices. Table 4 illustrates a comparison of improvement in performance in both cases.

Table 4: Comparison of improvement in performance in Case 1 and Case 2

Performance area	Case 1	Case 2
Level of wastes	Significant reduction in leakages, frequent breakdowns, energy consumption, unnecessary movements of workers and materials, accidents and wastes due to improper quality.	High energy consumption, high losses due to old equipment and improper maintenance, high losses due to improper quality and obsolete manufacturing processes.
Number of defects	Quality problems reduced by 10% and customer complaints reduced by 25%.	Often encountered poor and rejection of entire lots.
Productivity	Productivity increased by 1.5%.	Plant encountered heavy losses and several units were shutdown.
Manufacturing costs	Manufacturing costs reduced by 30%. Generated half million USD savings per year	Manufacturing costs increased in past five years.
First pass yield	First pass yield improved.	First pass yield did not change.
Level of inventories	Level of inventories decreased.	Level of inventories did not change.
Timely deliveries	Timely deliveries improved	Deliveries were generally delayed.
Small lot production	Small lot production was not visible.	Small lot production was not visible.
Space utilization	Efficient space utilization was not visible	Efficient space utilization was not visible

A closer look at Cases 1 and 2 revealed that both were government-owned, high-turnover profit making companies. However, Case 1 was enjoying a gradual increase in profits every successive year and was expanding its operations, whereas Case 2 was declared a sick unit. The plant was running at a loss and most of the units of the plant were shut down. Case 1 adopted a wide spectrum of lean practices for continuous running of equipment, waste reduction, quality improvement, employee empowerment, productivity improvement, technological upgrades and other such initiatives. However, Case 2 still used obsolete technology and very old equipment not arranged for employee empowerment through active participation, training and education. The management did not initiate efforts to reduce wastes and energy consumption and other expenditures.

6. Discussion and Implications

The outcome of this study suggests that there are significant differences in the average operational performance between adopters and non-adopters of lean practices. Performance differences are significant for measures such as first pass yield, level of wastes, improvements in quality, demand management, inventory levels, and productivity improvement.

The findings of this study are consistent with findings of McKone *et al.* (2001) conducted in US, Italy, Germany, and Japan suggesting that the implementation of lean practices is positively related with manufacturing performance. However, with regard to space utilization, lot size reduction, manufacturing flexibility, and employee flexibility, this study does not find a significant difference between *lean* adopters and non-adopters. These findings are counterintuitive to previous research (Boyle and Scherrer-Rathje, 2009; Fullerton and McWatters, 2001).Possibly, the piecemeal approach towards the application of lean practices such as quick change over techniques, job rotation, cross functional employees, pull production, and production levelling is responsible for this. These shortcomings were also attributed to the fact that the Indian process industries still work under a make-to-stock environment with seasonal availability of raw materials resulting in the need for increased space utilization for storage purposes. Further, Indian process industries possess high capacity and highly inflexible equipment and are still not able to find ways to utilize small lot size while maintaining the economies of scales.

Academically, this paper contributes to the body of knowledge of the existing lean manufacturing literature by narrowing the gap in the process industry, especially with respect to impact of lean practices on specific performance metrics in India. The research methodologies used in the paper are well grounded in existing literature and the findings are in alignment with those of similar studies. Thus this research provides a good foundation for future studies in lean process industries in other developing or emerging countries in the world. From the practitioner's perspective, this research helps clarify the ambiguity about the applicability of lean in process industries. It should certainly motivate the Indian process industry managers to further explore the possibilities of adopting lean. The paper has shortlisted the areas where lean can be primarily beneficial in process industries; therefore this study provides an idea to the managers to decide the targets of implementing lean. The case studies presented in the paper can be a benchmark for other companies who are considering the adoption of lean their facilities and processes.

7. Conclusions and Future Research

Our study investigated performance improvements due to implementation of *lean* in Indian process industries. A survey complemented by two case studies was carried out to investigate if adopting *lean* resulted in performance improvement in the process industry. Our findings suggested that the participating process industries observed reduction in wastes, reduction in cost, reduction in inventories, increase in quality, increase in timely deliveries and productivity through adoption of lean practices. Conversely, among the Indian process industries surveyed in this study, there was no significant difference in level of performance between *lean* adopters and non-adopters with respect to lot size reduction and space utilization.

Like any other research results, the findings of this research should also be viewed with following limitations. First, although in our study, the sample size was large enough and very representative, few additional studies would be appropriate for generalization of the findings. More importantly, considering the fact that the concept of *lean* is new for Indian process industries, more case studies representing wider sectors of process industry is needed before generalizing the conclusions. Finally, although in our research we included only those respondents who have adopted lean as a primary method for performance improvement, other methodologies such as theory of constraints, six sigma, etc. can also contribute to improvement in performance.

This study can be extended in multiple ways. First, as mentioned earlier, more empirical studies highlighting the methods and benefits of implementing lean manufacturing are required from different sectors within process industries from India and abroad for generalization of the results. The proliferation of such studies will not only increase the understanding of the *lean* concepts and encourage the process industries to implement *lean*, but will also provide guidelines for implementation. Further, it is also imperative to establish a statistical relationship between lean practices and performance improvement so that performance improvement through implementation of *lean* can be quantified and predicted. Lastly, conventional cost accounting methods in a lean manufacturing environment often results in misjudgment of performance improvement through adoption of *lean* (Ruiz-de-Arbulo-Lopez*et al.,* 2013). Therefore, further research is required to develop methods to analyze the benefits of adopting lean practices in process industries.

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Appendix I: Survey items used in this study

1. Kindly specify the type of your company according to the product:

(Chemical, Food and drink, Textile, Steel, Plastics and rubber, Cement, Sugar, Ceramics, Paper, Petroleum, Pharmaceuticals, Beverages, other)

2. Please specify the total investment in plant and machinery of your plant? ____________

3. What are the annual sales of your company?____________

4. Are you familiar with Lean/ JIT manufacturing: Yes/ No

5. Has your organization implemented Lean/ JIT manufacturing or its tools? Yes/No

6. Kindly specify the lean tools/ techniques you have implemented and the degree of implementation on a 5 point Likert scale: (1= not used, 2= seldom used, 3=sometimes, 4=often used, and 5= always used)

S.No.	Lean tools/ practices	1	2	3	4	5
1	Total productive maintenance					
2	5S					
3	Quality management programme					
4	Work standardization					
5	Statistical process control					
6	Continuous improvement programmes					
7	Visual control					
8	Long term relationship with suppliers					
9	Flexible and cross functional teams					
10	Small number of supplier					
11	Bottleneck/ constraint removal					
12	Supplier integration and partnership					
13	New equipment and technology					
14	Lot-size reduction					
15	JIT purchasing					
16	Quick changeover techniques					
17	Pull production					
18	Production levelling					

7. Kindly specify the level of improvement in following performance metrics in your industry (1= very high, 2= moderately high, 3= high, 4= low, 5= very low)

Performance criteria	1	2	3	4	5
Inventory levels					
Timely deliveries					
Level of various costs					
Level of wastes					
Productivity					
Defect levels					
First pass yield					
Timely deliveries					
Small lot production					