Lean Implementation in Pakistani Process Industries

Asim Amjad
Institute of Quality and Technology Management
University of the Punjab, New Campus
Lahore, Pakistan
asim.iqtm@pu.edu.pk

Iqra Ramzan
Department of Mechanical Engineering
University of Management and Technology
Lahore, Pakistan
iqra.ramzan@umt.edu.pk

Hafiz Muzammal Hussain
Institute of Quality and Technology Management
University of the Punjab, New Campus
Lahore, Pakistan
muzammalvirk@yahoo.com

Abstract

In the present era of competition, industries are adopting lean manufacturing for successful survival. The purpose of this study is to investigate the status of lean manufacturing in Pakistani process industries in terms of lean practices, reasons, and challenges of implementing lean manufacturing. A survey was carried out to assess the level of lean implementation in Pakistani process industries. 150 process industries were contacted, in which 84 industries were responded. Major process industrial sector includes food and beverages, chemical processing, oil refineries etc. The managers were requested to provide valuable information regarding lean implantation. The reliability of questionnaire is 0.935. Statistical tests were conducted to assess the significant lean practices, reasons, and challenges of implementation of lean. It is observed that the level of implementation of lean manufacturing in Pakistani process industries is still low. Results indicate that the process industries who implemented the lean found to be very useful to reduce wastes and to increase quality. These practices are concerned with to eliminate the waste and quality improvement. It was investigated that major challenges are reduction in setup time and lean experts who facilitate the employees for lean production. In the present study, the sample size is small and hence, the findings ought to be generalized cautiously. Although the study indicates that implementation of lean is useful for Pakistani process industries but to quantify performance improvements through adoption of lean requires increased research work.

Keywords
Lean implementation, Process industries, Pakistan, Lean production, and Waste reduction.

1. Introduction
Lean manufacturing is a new term and introduced by Krafcik (AlManei et al. 2017). After the Second World War Japan evolved a new technology in production system called "Lean Manufacturing" for Toyota Production System (TPS). The aim of lean manufacturing is, attain the equivalent or increased output with equivalent or low input such as specified time limits, less space, less labor, less machinery and overall less cost (Womack et al. 2007). The five-step thought process for guiding the implementation of lean techniques is shown in Figure 1.

Customer's need for a specific product will define the value. What and when product is delivered to the customer? What should be the price so the customer's expectations must be met? All these questions define the value. After

deciding the value next step is mapping the "value stream", defining all the steps and processes that involved in manufacturing or process of some product i.e. starting from raw material to the end finished product. It may be simple for discrete manufacturing industry but for process industry it will be very difficult task. This process will start from design, production, processing, procurement, HR, administration, Humane Resources, delivery, or customer service. After the removal of waste from value mapping the next step is to ensure the smooth implementation without any interruptions and or bottlenecks. This step should be implemented in a very tight sequence so that timely process of material should be ensured. The products are "pull" by customers as per their need either in a week or in a month. Result is not to build up large inventory and money saving that is beneficial for both customer and manufacturer.

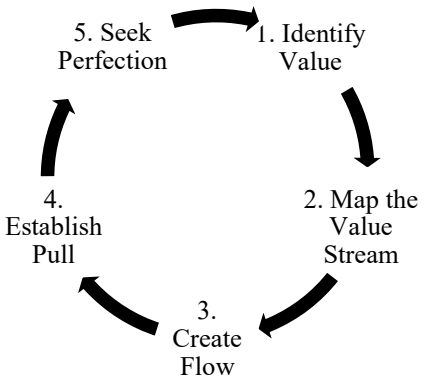

Figure 1: Five-step process for guiding the implementation of lean techniques (Womack et al. 2007)

There are many factors that are needed to be considered when planning to implement lean without the risk of any conflicts. Manufacturing organizations persistently doing efforts for improved performance to survive successfully in the present era of tough competition (Abdullah et al. 2008). As mentioned by Ghosh (2012), after the freedom of ideas and open market policies manufacturing businesses are also trying to indulge in the heat of competition. The intensity of competition is increased in every sector of industry no matter it is manufacturing industry, process or discrete on. Upadhye et al. (2010) mentioned due to severe competition, cost reduction and improved customer satisfaction is major concern in manufacturing sector and they are trying to find tools for improvements.

The process industries have been under continuous pressure to reduce operating cost and improve product quality and quantity. The manufacturing cost was excellent in the past but now this is not true. The competitors around the world are doing better and it must keep up. The customers are also grumbling and react to demand changes fast enough (Ghosh 2012). Not all companies can implement the same set of practices. Generally, the success of any management practice depends on organizational characteristics (Sousa and Voss 2008 as cited in Borges et al. 2015). Likewise, implementing lean is not straightforward, if not properly planned it will raise many obstacles, such as (Hodge et al. 2011 as cited in Borges et al. 2015): resistance to change; reluctance in contributing with suggestions for improvement; lack of motivation; and lack of knowledge of the lean philosophy and its tools.

Usually, the lean model is taken as discrete manufacturing tool and is useful for the products that are easily taken together. While on the other side the process industry converts raw material into consistent state that further mixed to form a final product. The final product of process industry cannot join and break together again. But in process sector its application is limited. Moreover no literature also represents the exact measurements and benefits of lean so it creates lesser awareness among industries of Pakistan (Panwar et al. 2015). Industries that are already practicing the process layout; the implementation of new technology is difficult for industry as well as people working in it (King 2009).

The primary purpose of study is to determine whether Pakistani process industries adopt this technology as a useful tool or not? Also, either this tool of manufacturing has been or started to be implemented in Pakistani process industry or not? Afterward, why should adopt lean in Pakistan process industries? This study will not help the Pakistani industries how to use lean but also help to target how this tool will be beneficial for industries. In contrast all questions of adoption it is important to highlight the challenges suffered by adopting lean. Without the study of challenges, it is useless to discuss any parameter. The process of lean is highly successful if it is implemented through proper direction

and care. If the challenges regarding lean implementation dealt carefully, success of lean can be increased to high degree. Finally, as studied from literature it seems and concluded that lean is successful tool for waste reduction and elimination then why industrial sector of Pakistan is it reluctant to opt lean? This study is the first attempt to fill this gap in research and will examine various aspects of implementation of lean manufacturing in process sector of Pakistan.

The benefits of lean production are increasing day by day because of its high success impact on the culture of an organization. Various articles have been published in different journals regarding its success. From the past few year's reviews from 2006-2011 one can see rapid change in performance of lean and it will be considered to be increased in future also (Jasti and Kodali 2015). Marodin and Saurin (2013) also found that drastic change in lean results for 50% of article in last few years of study. After analyzing different process industries this can be helpful for prospects of lean implementation. It will be useful and motivating to identify how lean can be adventitious or not in process industry. Every country industrial sector is the second largest sector of the economy. The industrial sector of Pakistan plays second largest individual role of the economy that accounts 25 percent of the GDP. The large, medium and small scale organizations comes under industrial sector (Jaleel 2012).

2. Literature Review

Process industries involve processes that involved continuous flow line (Dennis and Meredith 2000).The final product of these process are mostly non discrete items i.e. chemicals, gases, slurries, powders, and liquid solutions , and these items cannot be saved without any container. Fransoo and Rutten (1994) after studying found that there is high inventory of process industries "work in process (WIP)" while on the other side flow processes involve continuous long setup with high batch production. Such industries are less flexible towards the changes and follow the already scheduled simple flow and single routing. Shah (2005) suggests that high inventories in supply chain and lesser material efficiency (approximately 10%) and operations having no value added to the whole process are linked with process industries. Process industries have inventory of about 24% and Just in time (JIT) tool can be of great source for inventory control (Tawfik Mady 1991). Roy and Guin (1999), studied on Iron manufacturing industry and suggested that JIT can save large cost of inventory. Seasonal availability of raw material and there processing equipment is also counted as a waste that can be counted in other type of wastes in process industry and such wastes can be controlled through lean implementation.

Many industries work on strategy that is "make and stock". Hence there is huge inventory of raw materials, final products, and other materials. The purpose of lean is maximum utilization of space and equipment (Cox et al. 2005, Billesbach 1994). The result is reduced the problems and minimize the bottlenecks which reduces the chances of rework and unnecessary processes can be avoided. The major concern of lean is cost reduction and other assets that involved in specialized equipment, environmental considerations and high degree of automation (Ashayeri et al. 1996). As the flow in process industry is continuous and run without any hindrances. There is no stop in between the processes, it leads to major productivity loss. But excessive use of pumps, motors and machinery in process industries leads to sudden and frequent breakdown (Billesbach 1994). Tools of lean like "total productive maintenance" (TPM) and 5S can be used and most effective for continuous production without any breakdown (Sharma et al. 2005). The setup time for process industries is much larger compared to other as it involves processes like cleaning, separation and washing of processing equipment's (Billesbach 1994). To reduce setup time lean manufacturing techniques like quick changeover and reduction in setup time quick changeover can be useful.

Other than above stated causes Cook and Rogowski (1996) described that the lean techniques can lead to reduce in time of manufacturing to delivery (lead time) and its inconstancy and give precision for future demand estimating which result in saving huge amount of working capital of process industries. As indicated by Zanoni and Zavanella (2005), time and temperature are basic parameters upon which processes in process industry depends, heating in kiln, food processing, drying in paper and sugar industry and manufacturing of steel. All of these processes are mostly done in an industry's warehouse and are very critical regarding customer's point of view because delay in any one of the processes can affect the whole processing line that reduces the quality of product. Just in time "JIT" and "pull production" tools can be used for processes to be carried out timely. (Dov 1992) proved that to satisfy the quality of product at customer's end JIT techniques such as "JIT deliveries," kanban and "pull production" are very effective. Surprisingly, (Gunasekaran 1998) found that instead of very low operational efficiency, industries are very reluctant to apply all the method. Few of them has been applied in industry.

To check the feasibility of relevant issue all the data and their outcomes from the different researchers all over the word has been summarized in a single table. This empirical data will be helpful for the implementation of lean in process industries. Findings from analysis is shown in Table 1.

Table 1. Survey studies regarding lean implementation in process industries

Literature Reference	Type of Industry and Geographical Area	Focus of Investigation	Key Findings
(Tawfik 1991)	44 manufacturing enterprises in Egypt including textile, food and chemical companies	Effect of type of industry on inventory control	Inventory represents 24 percent of total assets in process industries. Techniques such as MRP, JIT, *Kanban*, and zero inventory are useful for inventory management
(White 1993)	494 US manufacturing firms including large portion of process industries	Benefits of JIT implementation	90 percent gained benefits from implementing JIT. JIT is helpful in reducing lead time, decreasing throughput time, improving production quality, increasing productivity and enhancing customer responsiveness
(Sohal and Egglestone 1994)	51 Australian industries including 69 percent industries from process sector	Status of lean implementation	82 percent industries were practicing lean manufacturing. Substantial benefits can be achieved through implementation of lean manufacturing despite of type or size of industry
(Besson and Haddadj 1999)	50 US chemical firms	Effect of employees' skill on lean adoption	Successful implementation of lean manufacturing needs elevation in employees' skills
(Amoako-Gyampah and Gargeya 2001)	48 manufacturing firms in Ghana (most of the firms are from process sector)	Status of JIT implementation	Same fundamental understanding of JIT as in developed countries. JIT manufacturing firms give emphasis on employees' training, cellular manufacturing, setup time reduction, continuous quality improvement and supplier relationship
(Soriano-Meier and Forrester 2002)	Survey of 30 UK ceramics industries	Factors affecting JIT implementation	Lean production's effects can only be seen in long term. There exists strong relationship between managerial commitment and JIT implementation
(White and Prybutok 2001)	494 US manufacturing firms (including continuous flow industries)	Comparison of JIT practices implementation	Repetitive process industries have higher utilization of JIT practices in comparison with non-repetitive industries like job or batch production
(Shah and Ward 2003)	1748 US manufacturing firms	Investigation of lean practices implementation	Lean implementation depends on plant age and size but not on type. JIT practices are more common in discrete industries and TPM practices are more likely to be implemented in process industries
(Fullerton 2003)	253 US firms including 58 process industries	Benefits of implementing JIT	Only 14 out of 58 process industries were using JIT. JIT firms are more profit earning than non-JIT firms

Literature Reference	Type of Industry and Geographical Area	Focus of Investigation	Key Findings
(Ismail 2005)	94 Manufacturing firms in Egypt (including 34 process industries)	Status of JIT implementation	16.08 percent food industries and 25 percent chemical industries had implemented JIT philosophy. Implementing JIT can significantly improve the performance. It can be successfully implemented just like in USA or Japan
(Bonavia and Marin 2006)	76 ceramic tile industries in Spain	Investigation of lean practices implementation	Most lean practices are still not widespread. Quality control and TPM are common whereas other practices are absent. Lean practices generally do not depend on plant size
(Taj 2008)	65 Chinese industries including textile, chemical, petroleum and food industries	Areas of lean assessment	The major areas of lean assessment are inventory, team approach, process, maintenance, layout and handling, suppliers, setup, quality, and scheduling/control. Petroleum industry has shown highest level of performance on these assessment areas
(Koumanakos 2008)	1,358 Greek process industries including food, chemical and textile	Benefits of lean implementation	Higher the inventory level, lower the rate of return. Lean manufacturing makes an industry more efficient in terms of profitability
(Abdullah et al. 2008)	36 cement industries in Libya	Reasons of non-implementation of JIT	Only 14 percent were implementing JIT. Prominent reasons were lack of top management support and unfamiliarity with JIT practices. Although JIT implementation is perceived as a useful methodology
(Moriones et al. 2008)	203 industries in Spain including major part from food and drink, chemical, paper, rubber and plastic, primary metal and textile	Factors affecting JIT implementation	JIT can be applied in any production setup and does not depend on size or age of plant. JIT implementation is low in paper and textile industries. Advanced manufacturing technology, quality management, collaboration with suppliers and customers and, work organization positively affect JIT implementation
(Chen and Shang 2008)	Survey of 246 Chinese industries including 107 process industries	Status of JIT and MRP implementation	JIT has been widely accepted in China. 84 process industries included in survey were using only JIT or a combined MRP/ JIT system. Most notable JIT components are "setup reduction", 5S, kaizen, "cross training" and "multi-functional team." Kanban and "pull production" are rarely used
(Scott et al. 2009)	46 respondents from Canadian food manufacturing industry	Investigation of continuous Improvement programe	23.1 percent food processing units have implemented lean manufacturing as structured continuous improvement programe
(Abdullah et al.	32 iron and steel	Investigation of	Only 17 percent industries were using

Literature Reference	Type of Industry and Geographical Area	Focus of Investigation	Key Findings
2010)	industries in Libya	status of JIT and MRPII	JIT/MRPII. Managerial commitment is must to incorporate JIT
(Gebauer et al. 2009)	95 pharmaceutical organizations from 20 European countries	Investigation of lean manufacturing adoption	Plant size and company type have positive effect lean implementation. Lean manufacturing helps to enhance operational performance. The adoption rate of lean manufacturing in pharmaceutical sector is still low
(Rahman et al. 2010)	187 manufacturing firms in Thailand including process industries such as food and textile	Comparison of large and small industries in regards to lean practices implementation	Large industries emphasize more on JIT whereas small industries emphasize more on waste minimization. Adoption of lean manufacturing significantly affects operational performance
(Small et al. 2011)	64 USA firms including 37 process industries	Assessing the implementation of process management initiatives	In low or moderate level of technology firms, *kaizen*, benchmarking and TQM were more popular initiatives in comparison with lean manufacturing
(Bhasin 2012)	68 UK manufacturing firms including process industries	Obstacles to adopt lean	Major obstacles to implement lean are "insufficient supervisory skills to implement lean," "insufficient workforce skills to implement lean," "resistance to change" and "insufficient senior management skills to implement lean"
(Lyons et al. 2013)	62 UK process industries	Implementation of lean practices	Only those lean practices are extensively used in process industries which are associated with elimination of wastes. Use of 5S, TPM, quality management, visual control and SPC is widespread, whereas use of cellular manufacturing, JIT production and pull production is rare

From Table 1 it can be seen clearly there is substantial weightage of improvements in inventory in process industries, elimination and reduction of waste, customer satisfaction, quality management and continuous improvements (Gebauer et al. 2009, Koumanakos 2008, Tawfik 1991). However, discrete industries adopted lean more rapidly than process industries. And lean manufacturing is common for discrete type industries rather than process (Small et al. 2011). Hence, most of the lean practices are not very common in process industries (Bonavia and Marin 2006). Adoption rate of "lean" is higher in developed countries like European side, Australia and china as depicted by Table 1. while developing countries have low trend of lean implementation in manufacturing sector (Abdullah et al. 2008, Abdullah et al. 2010).

3. Methods

A survey form has been generated based on the problem. Before finalizing a draft has been prepared and discussed it with experts for better quality of research. The final format is spread in different industries and data has been collected. There are three major portions of questionnaire. In first section there are five questions that contained general information of an organization like name, type of process etc. In second section there are three questions that covers the answers related to lean implementation awareness. Last section of the questionnaire comprises on issues related to lean manufacturing that industry can be faced. Four questions has been discussed in the last part to identify "reasons of not implementing lean," "reasons of implementing lean," "lean practices" and "challenges while implementing lean," respectively. Issues related to lean implantation and their related items along with literature resources is summarized in Table 2.

Table 2. Literature summary of lean issues and test of reliability for internal consistency

Lean Implementation Issue	No. of items	Items	Literature Source	Cronbach's α
Reasons of implementing lean	07	• Elimination of wastes • To decrease production costs • To improve quality • To facilitate JIT production • To increase customer satisfaction • To increase supply chain efficiency • To increase utilization of space	(White 1993, Taj 2008, Singh et al. 2010b)	0.906
Lean practices	16	• Value stream mapping (VSM) • 5S • Setup reduction • Lot-size reduction • Total productive maintenance (TPM) • Work standardization • Statistical process control (SPC) • Quality management programs • Takt time • Pull production • Production levelling • Kanban • Flexible and cross functional teams • Continuous improvement programs • Supplier integration and partnership • Long-term relationship with suppliers	(Shah and Ward 2003, Lyons et al. 2013)	0.829
Challenges to implement lean	10	• To facilitate small batch production • To identify techniques for setup time reduction • To deal with typical process characteristics (time and • temperature, etc.) • To arrange lean implementation experts • Lack of training • Short lead times • Perishable nature of products • Improper information exchange across supply chain • To facilitate JIT production • To facilitate JIT purchasing	(Bhasin 2012, Ezingeard and Race 1995, Houghton and Portougal 1995, Powell et al. 2010, van der Vorst et al. 2001)	0.628
Reasons of not implementing lean	08	• Large batch production is necessary for capacity utilization • Process industries already have continuous	Ezingeard and Race (1995),	0.721

Lean Implementation Issue	No. of items	Items	Literature Source	Cronbach's α
		production • Lack of education and expertise on lean • Lack of financial resources • Lack of time • Cultural barriers (resistance to change) • Lack of senior management's interest and support • Lean is complex to implement	Hokoma *et al.* (2008), Hokoma *et al.* (2010)	

Likert 5-point scale ranges 1 = "not use at all" up to 5 = "always use," will be used for the measures of "lean practices." Same level scale has been utilized for all remaining issues items, ranges from 1 = "not important" to 5 = "most important." For the given analysis Simple Random Sampling (SRS) has been used. In this type the probability of occurrence of each sample is equal. It does not require any division of samples but if the sample has not meet the end requirement of analysis then it will create difficulties. To check the consistency of results a reliability test has been carried out. A factor Cronbach's α has been calculated for all reactions collected from survey. Result variables with value of α more than 0.60 has been considered highly consistent. For all the issues addressed in questionnaire reliability test has been done. Final conclusion is showed in Table 2. More the value of coefficient of Cronbach's α indicates that there is internal evenness of all factors of the related concerns. The complete questionnaire reliability score is 0.935.

4. Data Collection

The targeted population is process industrial sector of Pakistan. Major process industrial sector includes food and beverages, chemical processing, oil refineries etc. The managers of Pakistani process industries were requested to provide valuable information regarding lean implantation in Pakistani process industries. 150 Pakistani process industries were contacted, in which 84 industries were responded. The achieved rate of contacted response was 56 percent.

5. Results and Discussion

From 150 Pakistani process industries 15 industries have not implemented lean practices. For finding the significant motives of not implementation of lean, one sample t-test, the t- test has been carried for value 3. Table 3 shows the reasons mean scores and rank values of not executing lean practices in Pakistani process-based industries. The statistics of one sample are also shown in Table 3. Table 4 shows the significant reasons of not implementing lean are "Cultural barriers (resistance to change)" (8.791, 0.000) and "Lack of senior management's interest and support" (6.292, 0.000). Nevertheless, the other major and most significant reason behind not implementation of lean is that industries are already going through continuous production. While on other side, process industries of Pakistan do not follow the typical process characteristics like "dependence of process on time and temperature" are substantial reasons behind not accepting lean. Amazingly, Large batch production is essential for capacity utilization, Lack of financial resources and Lack of education and expertise on lean are also not considered as important reasons of not applying "lean" practices. The one sample statistic of t-test is shown in Table 5.

Table 3. Rank table base on mean and t statistics

Reasons of not Implementing Lean	Mean	Rank	t
Large batch production is necessary for capacity utilization	3.67	3	5.604
Process industries already have continuous production	2.87	8	-1.586
Lack of education and expertise on lean	3.40	5	3.976
Lack of financial resources	3.63	4	4.665
Lack of time	3.33	7	2.059
Cultural barriers (resistance to change)	3.86	1	8.791
Lack of senior management's interest and support	3.69	2	6.292
Lean is complex to implement	3.35	6	2.712

Table 4. One sample t-test for reasons of not implementing lean

Reasons of not Implementing Lean	t	df	Sig. (2-tailed)	Mean Difference	95% CI	
					Lower	Upper
Large batch production is necessary for capacity utilization	5.604	83	.000	.667	.43	.90
Process industries already have continuous production	-1.586	83	.117	-.131	-.30	.03
Lack of education and expertise on lean	3.976	83	.000	.405	.20	.61
Lack of financial resources	4.665	83	.000	.631	.36	.90
Lack of time	2.059	83	.043	.333	.01	.66
Cultural barriers (resistance to change)	8.791	83	.000	.857	.66	1.05
Lack of senior management's interest and support	6.292	83	.000	.690	.47	.91
Lean is complex to implement	2.712	83	.008	.345	.09	.60

Table 5. One sample t-test statistics

Reasons of not Implementing Lean	N	Mean	Std. Deviation	Std. Error Mean
Large batch production is necessary for capacity utilization	84	3.67	1.090	.119
Process industries already have continuous production	84	2.87	.757	.083
Lack of education and expertise on lean	84	3.40	.933	.102
Lack of financial resources	84	3.63	1.240	.135
Lack of time	84	3.33	1.484	.162
Cultural barriers (resistance to change)	84	3.86	.894	.098
Lack of senior management's interest and support	84	3.69	1.006	.110
Lean is complex to implement	84	3.35	1.167	.127

For finding the significant reasons of implementing lean in Pakistani process industries, 1 sample t-test with value of 3 is chosen. The ranks of reasons of implementing lean practices in Pakistani process industries based on the mean and also the t-statistics, shown in Table 6. The major concerns behind lean implementation in Pakistan's process industries is "To decrease production costs" (6.454, 0.000), shown in Table 7. Other important reasons of implementing lean are "To increase utilization of space" (5.145, 0.000), "To increase customer satisfaction" (4.260, 0.000), and "Elimination of wastes" (-2.211, 0.030). Nevertheless, the current study revealed that in Pakistani process industries "To improve quality", "To facilitate JIT Production" and "to increase supply chain efficiency" are not substantial reasons of implementation of lean practices in Pakistan. The one sample statistic of t-test is shown in Table 8.

Table 6. Rank table base on mean and t statistics

Reasons of Implementing Lean	Mean	Rank	t	Sig. (2-tailed)	Mean Difference
Elimination of wastes	2.61	7	-2.211	.030	-.393
To decrease production costs	4.08	1	6.454	.000	1.083
To improve quality	3.10	5	.591	.556	.095
To facilitate JIT Production	3.26	4	1.916	.059	.262
To increase customer satisfaction	3.70	3	4.260	.000	.702
To increase supply chain efficiency	2.81	6	-1.726	.088	-.190
To increase utilization of space	3.80	2	5.145	.000	.798

Table 7. One sample t-test for reasons of implementing lean

Reasons of Implementing Lean	t	df	Sig. (2-tailed)	Mean Difference	95% CI	
					Lower	Upper
Elimination of wastes	-2.211	83	.030	-.393	-.75	-.04
To decrease production costs	6.454	83	.000	1.083	.75	1.42
To improve quality	.591	83	.556	.095	-.23	.42
To facilitate JIT Production	1.916	83	.059	.262	-.01	.53
To increase customer satisfaction	4.260	83	.000	.702	.37	1.03
To increase supply chain efficiency	-1.726	83	.088	-.190	-.41	.03
To increase utilization of space	5.145	83	.000	.798	.49	1.11

Table 8. One sample t-test statistics

Reasons of Implementing Lean	N	Mean	Std. Deviation	Std. Error Mean
Elimination of wastes	84	2.61	1.628	.178
To decrease production costs	84	4.08	1.538	.168
To improve quality	84	3.10	1.478	.161
To facilitate JIT Production	84	3.26	1.253	.137
To increase customer satisfaction	84	3.70	1.511	.165
To increase supply chain efficiency	84	2.81	1.012	.110
To increase utilization of space	84	3.80	1.421	.155

For finding the lean tools that were significantly used in Pakistani process industries one sample t-test with test value of 3 is used, as shown in Table 9. According to Table 9, significantly higher used lean tools are "Value stream mapping" (-41.408, 0.000), 5S (4.256, 0.000), "Setup reduction" (-5.006, 0.000), "Lot-size reduction" (3.250, 0.002), SPC (-6.335, 0.000), "quality management program" (-4.693, 0.000), "Takt time" (-2.387, 0.019), "Pull production" (-5.170, 0.000), "Kanban" (-4.157, 0.000), "Flexible and cross functional teams" (-5.979, 0.000), "Continuous improvement programs" (3.409, 0.001), "Supplier integration and partnership" (-9.039, 0.000), and "Long term relationship with supplier" (-5.464, 0.000). Practices of lean that are not very common in process industries of Pakistan are "Total productive maintenance", "Work standardization", and "Production leveling." The one sample statistic of t-test is shown in Table 10.

Table 9. One sample t-test for use of lean tools

Lean Tools	t	df	Sig. (2-tailed)	Mean Difference	95% CI	
					Lower	Upper
Value stream mapping (VSM)	-41.408	83	.000	-1.833	-1.92	-1.75
5S	4.256	83	.000	.655	.35	.96
Setup reduction	-5.006	83	.000	-.726	-1.01	-.44
Lot-size reduction	3.250	83	.002	.500	.19	.81
Total productive maintenance (TPM)	-.993	83	.324	-.143	-.43	.14
Work standardization	.300	83	.765	.036	-.20	.27
Statistical process control (SPC)	-6.335	83	.000	-.881	-1.16	-.60
Quality management program	-4.693	83	.000	-.667	-.95	-.38
Takt time	-2.387	83	.019	-.417	-.76	-.07
Pull production	-5.170	83	.000	-.940	-1.30	-.58
Production leveling	-1.041	83	.301	-.202	-.59	.18
Kanban	-4.157	83	.000	-.655	-.97	-.34
Flexible and cross functional teams	-5.979	83	.000	-.667	-.89	-.44
Continuous improvement programs	3.409	83	.001	.452	.19	.72
Supplier integration and partnership	-9.039	83	.000	-.929	-1.13	-.72
Long term relationship with supplier	-5.464	83	.000	-.476	-.65	-.30

Table 10. One-Sample t-test Statistics

Lean Tools	N	Mean	Std. Deviation	Std. Error Mean
Value stream mapping (VSM)	84	1.17	.406	.044
5S	84	3.65	1.410	.154
Setup reduction	84	2.27	1.329	.145
Lot-size reduction	84	3.50	1.410	.154
Total productive maintenance (TPM)	84	2.86	1.318	.144
Work standardization	84	3.04	1.092	.119
Statistical process control (SPC)	84	2.12	1.274	.139
Quality management program	84	2.33	1.302	.142
Takt time	84	2.58	1.600	.175
Pull production	84	2.06	1.667	.182
Production leveling	84	2.80	1.782	.194
Kanban	84	2.35	1.444	.158
Flexible and cross functional teams	84	2.33	1.022	.111
Continuous improvement programs	84	3.45	1.216	.133
Supplier integration and partnership	84	2.07	.941	.103
Long term relationship with supplier	84	2.52	.799	.087

Table 11 depicted the findings of one sample t-test (test value is taken 3) to prevailed the major challenges that has shown the results of one sample t-test (test value 3) to find major challenges that Pakistan's process industries may confronted during implementation of lean in process sector. The study found that "To identify techniques for setup time reduction", "To deal with typical process characteristics (time and temperature etc.)", "To arrange lean implementation experts", "Lack of training", "Short lead times", "Perishable nature of products", "Improper information exchange across supply chain", and "to facilitate JIT purchasing". The one sample statistic of t-test is shown in Table 12.

Table 11. One sample t-test for challenges while implementing lean

Challenges while Implementing Lean	t	df	Sig. (2-tailed)	Mean Difference	95% CI	
					Lower	Upper
To facilitate small batch production	-.113	83	.911	-.024	-.44	.40
To identify techniques for setup time reduction	-7.436	83	.000	-1.095	-1.39	-.80
To deal with typical process characteristics (time and temperature etc.)	-4.429	83	.000	-.810	-1.17	-.45
To arrange lean implementation experts	-3.537	83	.001	-.393	-.61	-.17
Lack of training	-2.947	83	.004	-.548	-.92	-.18
Short lead times	-3.586	83	.001	-.464	-.72	-.21
Perishable nature of products	-7.442	83	.000	-.976	-1.24	-.72
Improper information exchange across supply chain	-12.017	83	.000	-.940	-1.10	-.78
To facilitate JIT production	-2.902	83	.005	-.500	-.84	-.16
To facilitate JIT purchasing	-3.164	83	.002	-.548	-.89	-.20

Table 12. One-Sample Statistics

Challenges while Implementing Lean	N	Mean	Std. Deviation	Std. Error Mean
To facilitate small batch production	84	2.98	1.939	.212
To identify techniques for setup time reduction	84	1.90	1.350	.147
To deal with typical process characteristics (time and temperature etc.)	84	2.19	1.675	.183
To arrange lean implementation experts	84	2.61	1.018	.111
Lack of training	84	2.45	1.703	.186
Short lead times	84	2.54	1.187	.129
Perishable nature of products	84	2.02	1.202	.131
Improper information exchange across supply chain	84	2.06	.717	.078
To facilitate JIT production	84	2.50	1.579	.172
To facilitate JIT purchasing	84	2.45	1.586	.173

Unexpectedly, Pakistani process industries do not observe "To facilitate small batch production" or "To facilitate JIT production" as significant challenge to implement lean. In the prescribed study process industries along with discrete industries has been selected for study purpose. The present study is mainly in Pakistan's process industry context. The process of implementation of lean in Pakistan is very slow and still at low level in comparison to other world industries like China, USA etc. (Chen and Shang 2008), though, the percentage is more than other industries of developing countries (Abdullah et al. 2010, Amoako et al. 2001). Survey results suggest that for Pakistani process industries leading reason of not implementing lean is "Cultural barriers (resistance to change)" (8.791, 0.000) and "Lack of senior management's interest and support" (6.292, 0.000). Inadequate training and education about lean is another major reason of not implementing lean. Besson and Haddadj (1999) studied and suggested that proper skills related to lean implementation are necessary for lean implementation in industry. Hokoma et al. (2008, 2010) stated that the main reason of not implementation lean is "unfamiliarity with JIT/TQM" but in context of Pakistan this statement is true somehow and concept is not clear about lean and it decreases the rate of implementation. Substantial reason behind not implementation lean in process industries of Pakistan is "To decrease production costs" (6.454, 0.000), shown in Table 7. Other major reasons of implementing lean are "To increase utilization of space" (5.145, 0.000), "To increase customer satisfaction" (4.260, 0.000), and "Elimination of wastes" (-2.211, 0.030). In process industries the quality of raw materials are variable and output is also vary accordingly. The quality of output also effect. Due to increasing competition in industrial sector, customers focus on superior quality. And these factors work as a driving push to improve the process through lean implementation. Reduction in delivery time, cost reduction, increased product variety can be achieved through lean implementation. And these factors are necessary to achieve to meet the current demand of high competition to survive in industrial sector. Hence it is necessary to encourage industrialists to implement lean both in discrete as well as process industries. Primarily lean tools that were used in the Pakistani process industries where lean implementation is practices are "Value stream mapping", 5S, "Setup reduction", "Lot-size reduction", SPC, "quality management program", "Takt time", "Pull production", "Kanban", "Flexible and cross functional teams", "Continuous improvement programs", "Supplier integration and partnership", and "Long term relationship with supplier". 5s implementation is very effective tool of lean and used in process industries Lyons (2013). To make work environment effective and making options for lean, 5S can be a successful tool. Also, 5S will reduce the non-value-added processes and activities at every stage. The use of these lean tools indicates to some important insights about lean implementation in Pakistani process industries:

- "5S", "TPM", "visual control," "work standardization," "quality management" and "continuous improvement" are lean tools but they are not specifically related to lean. They are considered as techniques used in management for layout, quality and considered as world class management techniques subsequently, it isn't shocking in the event that they are generally utilized as a part of Pakistani process ventures.
- As the experts who are implementing lean are not for specific industry so one can find them easily.
- Change in batch size is not a demand of lean tool so it can be easily implemented in Pakistan.
- Not only the quality will improve but also waste will be reduced.
- As from literature review it is clear that Value Stream Method can be worked as a primary tool while adopting lean in process industries. (Upadhye et al. 2010). But our findings depicted that VSM techniques are not very rare in process industries.

According to the results of the current study the most prominent challenges while implementing lean are "To identify techniques for setup time reduction", "To deal with typical process characteristics (time and temperature etc.)", "to arrange lean implementation experts", "Lack of training", "Short lead times", "Perishable nature of products", "Improper information exchange across supply chain", and "to facilitate JIT purchasing". During lean implementation in process industries the major hindrance is the main lead who take the team in effective manner suggested by Kamakura (2006). In Pakistan lean manufacturing is under developing stage. Secondly the lean tool is more common in discrete manufacturing area. So, experts required who devised lean tool very effectively is required for successful implementation. In a recent study of UK firms, Bhasin (2012) in his study suggested that "lack of supervisory skills to implement lean" is a major hindrance to implement lean. The important factors summarized from the present study are below, and that are necessary for successful lean implementation in reference to process industry:

- For Pakistani industries lean is new concept but majority of the industrial sector is aware of its effect and usage that it is a tool of continuous improvement.
- The startup to implement lean is almost same for both discrete manufacturing and process industries.
- Industries of Pakistan who has not implemented lean found that it is very useful tool to reduce the waste and increase quality of product.
- Significant concerns of lean in Pakistan are those that are related to elimination and reduction of waste and quality improvement.
- One of the biggest challenges is to provide proper training and to find expert who can implement lean very effectively.

6. Conclusion

The major concern of this study was to discover the how successful is the lean implementation in Pakistan's process sector industries. After the study of literature, the purpose of this study was to discuss the process of lean implementation is divided in to for heads, namely:

1. Why lean is not implemented,
2. Why lean should be implemented
3. Tools required for Lean tools, and
4. Challenges faced while implementing lean

After reviewing the questionnaire based on the data collected from multiple industries of Pakistan it is observed that lean implementation process is highly challenging till in Pakistan. As industries has already developed their culture so "Cultural barriers (resistance to change)" is the primary reason of not adopting lean. Moreover, higher authorities are not willing to accept any change as the process is already going in bulk mode so we can say "Lack of senior management's interest and support", "Large batch production is necessary for capacity utilization", "Lack of expertise," "lack of education" and "inadequate training" can be other factors of not success of lean implementation.

After studying it is concluded that lean practices like "Value stream mapping", 5S, "Setup reduction", "Lot-size reduction", SPC, "quality management program", "Takt time", "Pull production", "Kanban", "Flexible and cross functional teams", "Continuous improvement programs", "Supplier integration and partnership", and "Long term relationship with supplier" are extensive in Pakistani process industries. "Customer satisfaction" and "waste elimination" are the significant reasons behind the lean adoption. The findings based on the study done in different process industries of Pakistan suggest that to implement lean the major hurdles are "To facilitate JIT Production", "to increase supply chain efficiency" and "to arrange experts to implement lean".

The study performs on relatively smaller sample hence the results analysis should be done carefully. The study shows it is very useful if Pakistan's industries started implementing lean but it is suggested before implementation further analysis (empirical studies) should be carried out to reduce the chances of failure. As it is fact that lean implementation is new for Pakistani industries so to encourage the industries and for better results further research will explore more perspectives. These factors are worked as driving force to adopt lean in Pakistani process industries. Chowdary and George (2011) in his study concluded that operational areas creating major wastes are difficult to find for waste reduction. To implement lean tools related to "JIT production" such as "pull production" and Kanban in process sector research is required. As there are no evidence as such of lean implementations in Pakistan process industries even not at small scale so 1st step is to explore required possibilities to implement lean in small industries i.e. small food industries. Then analyze their issues separately. Finally discuss pros and cons of implementing and not implementing lean. Different sectors like cement, food, chemicals have different issues of implementation as it depends on nature of

process going in industry. It will also provide further tools and guidelines for every type of process industry. Increasing research will increase the chances of successful implementation of lean and break the barriers that cause hindrances in implementation in process sector. If following efforts has been done then lean implementation can be successful in Pakistan's process sector:

1. Educate industry resource persons about lean manufacturing. For this purpose, arrange seminars and trainings;
2. Implementation of VSM can help to identify areas of significant non-value-added activities where large benefits can be recognized;
3. It will be beneficial to start the implementation with low cost tool and done minor such as 5S, Total Productive Management, visual control, kaizen and "work standardization";
4. After minor changes move towards the major changes that are exploring possibilities for lean tools such as Kanban, "pull production," "JIT production" and "production levelling";
5. Carry out comparison of different tools especially on basis of function i.e. functional benchmarking and generic benchmarking to adopt lean manufacturing; and
6. Sign MOU with different process industries from all over the world that have gain success in lean implementation.

From above mentioning efforts one can emphasis on upgrading the operational and functional approaches of Pakistani process industries by implementing lean. As this can lead to reduce the waste and increase the productivity as well. The limitation or future aspects of lean may still exist that needs to be further investigation. The aspects are: Lean models for process industry, Key performance indicators, Supplier involvement, Best practices in lean management of process industries, Overcoming capacity constraints for continuous flow process industries, and More empirical studies.

References

Abdullah Hokoma, R., Khan, M. K., & Hussain, K. (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. https://doi.org/10.1108/17410380810898804

Abdullah Hokoma, R., Khurshid Khan, M., & Hussain, K. (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. https://doi.org/10.1108/17542731011024309

AlManei, M., Salonitis, K., & Xu, Y. (2017). Lean Implementation Frameworks: The Challenges for SMEs. *Procedia CIRP*, *63*, 750–755. https://doi.org/10.1016/j.procir.2017.03.170

Amoako-Gyampah, K., & Gargeya, V. B. (2001). Just-in-time manufacturing in Ghana. *Industrial Management & Data Systems*, *101*(3), 106–113. https://doi.org/10.1108/02635570110386562

Ashayeri, J., Teelen, A., & Selenj, W. (1996). A production and maintenance planning model for the process industry. *International Journal of Production Research*, *34*(12), 3311–3326. https://doi.org/10.1080/00207549608905092

Besson, D., & Haddadj, S. (1999). Strategies developed by US chemical firms to resolve their skill shortages. *Journal of European Industrial Training*, *23*(7), 353–362. https://doi.org/10.1108/03090599910287369

Bhasin, S. (2012). Prominent obstacles to lean. *International Journal of Productivity and Performance Management*, *61*(4), 403–425. https://doi.org/10.1108/17410401211212661

Bonavia, T., & Marin, J. A. (2006). An empirical study of lean production in the ceramic tile industry in Spain. *International Journal of Operations & Production Management*, *26*(5), 505–531. https://doi.org/10.1108/01443570610659883

Borges Lopes, R., Freitas, F., & Sousa, I. (2015). Application of lean manufacturing tools in the food and beverage industries. *Journal of Technology Management & Innovation*, *10*(3), 120–130.

Chen, Z., & Shang, J. S. (2008). Manufacturing planning and control technology versus operational performance: an empirical study of MRP and JIT in China. *International Journal of Manufacturing Technology and Management*, *13*(1), 4. https://doi.org/10.1504/IJMTM.2008.015971

Chowdary, B. V., & George, D. (2011). Improvement of manufacturing operations at a pharmaceutical company: A lean manufacturing approach. *Journal of Manufacturing Technology Management*, *23*(1), 56–75. https://doi.org/10.1108/17410381211196285

Cook, R. L., & Rogowski, R. A. (1996). Applying JIT principles to continuous process manufacturing supply chains, *37*, 12–16.

Cox, A., & Chicksand, D. (2005). The Limits of Lean Management Thinking: Multiple Retailers and Food and Farming Supply Chains. *European Management Journal*, *23*, 648–662. https://doi.org/10.1016/j.emj.2005.10.010

Dennis, D. R., & Meredith, J. R. (2000). An analysis of process industry production and inventory management systems. *Journal of Operations Management*, *18*, 683–699.

Dov, M. (1992). A manufacturing process with a different flavor: JIT and the ice cream industry. (just-in-time inventory systems). *Industrial Management*, *v34*(n2), p10(4).

Ezingeard, J., & Race, P. (1995). Spreadsheet simulation to aid capacity management of batch chemical processing using JIT pull control. *International Journal of Operations & Production Management*, *15*(10), 82–88. https://doi.org/10.1108/01443579510098347

Fransoo, J. C., & Rutten, W. G. M. M. (1994). A Typology of Production Control Situations in Process Industries. *International Journal of Operations & Production Management*, *14*(12), 47–57. https://doi.org/10.1108/01443579410072382

Fullerton, R. R. (2003). Performance measurement and reward systems in JIT and non-JIT firms. *Journal of Cost Management*, *17*(6), 40–48.

Gebauer, H., Kickuth, M., & Friedli, T. (2009). Lean management practices in the pharmaceutical industry. *International Journal of Services and Operations Management*, *5*(4), 463. https://doi.org/10.1504/IJSOM.2009.024580

Ghosh, M. (2012). Lean manufacturing performance in Indian manufacturing plants. *Journal of Manufacturing Technology Management*, *24*(1), 113–122. https://doi.org/10.1108/17410381311287517

Gunasekaran, A. (1998). Agile manufacturing: Enablers and an implementation framework. *International Journal of Production Research*, *36*(5), 1223–1247. https://doi.org/10.1080/002075498193291

Houghton, E., & Portougal, V. (1995). A planning model for just-in-time batch manufacturing. *International Journal of Operations & Production Management*, *15*(9), 9–25. https://doi.org/10.1108/01443579510099625

Ismail Salaheldin, S. (2005). JIT implementation in Egyptian manufacturing firms: some empirical evidence. *International Journal of Operations & Production Management*, *25*(4), 354–370. https://doi.org/10.1108/01443570510585543

J. Billesbach, T. (1994). Applying lean production principles to a process facility, *35*.

Jaleel, S. (2012). *Pakistan Industrial Growth*. The Rawalpindi Chamber of Commerce & Industry. Retrieved from www.rcci.org.pk/wp-content/uploads/2012/12/igtip.pdf

Jasti, N. V. K., & Kodali, R. (2015). Lean production: literature review and trends. *International Journal of Production Research*, *53*(3), 867–885. https://doi.org/10.1080/00207543.2014.937508

Kamakura, Y., International Labour Office, & Sectoral Activities Programme. (2006). *Corporate structural change and social dialogue in the chemical industry*. Geneva: ILO.

King, P. L. (2009). *Lean for the process industries: dealing with complexity*. Boca Raton, Fla.: CRC Press.

Koumanakos, D. P. (2008). The effect of inventory management on firm performance. *International Journal of Productivity and Performance Management*, *57*(5), 355–369. https://doi.org/10.1108/17410400810881827

Lyons, A. C., Vidamour, K., Jain, R., & Sutherland, M. (2013). Developing an understanding of lean thinking in process industries. *Production Planning & Control*, *24*(6), 475–494. https://doi.org/10.1080/09537287.2011.633576

Marodin, G. A., & Saurin, T. A. (2013). Implementing lean production systems: research areas and opportunities for future studies. *International Journal of Production Research*, *51*(22), 6663–6680. https://doi.org/10.1080/00207543.2013.826831

Moriones, A. B., Pintado, A. B., & Merino-Díaz-de-Cerio, J. (2008). The role of organizational context and infrastructure practices in JIT implementation. *International Journal of Operations & Production Management*, *28*(11), 1042–1066. https://doi.org/10.1108/01443570810910188

Panwar, A., Nepal, B. P., Jain, R., & Rathore, A. P. S. (2015). On the adoption of lean manufacturing principles in process industries. *Production Planning & Control*, *26*(7), 564–587. https://doi.org/10.1080/09537287.2014.936532

Powell, D., Alfnes, E., & Semini, M. (2010). The Application of Lean Production Control Methods within a Process-Type Industry: The Case of Hydro Automotive Structures. In B. Vallespir & T. Alix (Eds.), *Advances in Production Management Systems. New Challenges, New Approaches* (Vol. 338, pp. 243–250). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-16358-6_31

Rahman, S., Laosirihongthong, T., & Sohal, A. S. (2010). Impact of lean strategy on operational performance: a study of Thai manufacturing companies. *Journal of Manufacturing Technology Management*, *21*(7), 839–852. https://doi.org/10.1108/17410381011077946

Roy, R. N., & Guin, K. K. (1999). A proposed model of JIT purchasing in an integrated steel plant. *International Journal of Production Economics*, *59*(1–3), 179–187. https://doi.org/10.1016/S0925-5273(98)00099-1

Scott, B. S., Wilcock, A. E., & Kanetkar, V. (2009). A survey of structured continuous improvement programs in the Canadian food sector. *Food Control*, *20*(3), 209–217. https://doi.org/10.1016/j.foodcont.2008.04.008

Shah, N. (2005). Process industry supply chains: Advances and challenges. *Computers & Chemical Engineering*, *29*(6), 1225–1235. https://doi.org/10.1016/j.compchemeng.2005.02.023

Shah, R, & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management*, *21*(2), 129–149. https://doi.org/10.1016/S0272-6963(02)00108-0

Sharma, R. K., Kumar, D., & Kumar, P. (2005). FLM to select suitable maintenance strategy in process industries using MISO model. *Journal of Quality in Maintenance Engineering*, *11*(4), 359–374. https://doi.org/10.1108/13552510510626981

Singh, B., Garg, S. K., Sharma, S. K., & Grewal, C. (2010a). Lean implementation and its benefits to production industry. *International Journal of Lean Six Sigma*, *1*(2), 157–168. https://doi.org/10.1108/20401461011049520

Small, M. H., Yasin, M. M., & Alavi, J. (2011). Assessing the implementation and effectiveness of process management initiatives at technologically consistent firms. *Business Process Management Journal*, *17*(1), 6–20. https://doi.org/10.1108/14637151111105553

Sohal, A. S. (1996). Developing a lean production organization: an Australian case study. *International Journal of Operations & Production Management*, *16*(2), 91–102. https://doi.org/10.1108/01443579610109866

Sohal, A. S., & Egglestone, A. (1994). Lean Production: Experience among Australian Organizations. *International Journal of Operations & Production Management*, *14*(11), 35–51. https://doi.org/10.1108/01443579410068639

Soriano-Meier, H., & Forrester, P. L. (2002). A model for evaluating the degree of leanness of manufacturing firms. *Integrated Manufacturing Systems*, *13*(2), 104–109. https://doi.org/10.1108/09576060210415437

Taj, S. (2008). Lean manufacturing performance in China: assessment of 65 manufacturing plants. *Journal of Manufacturing Technology Management*, *19*(2), 217–234. https://doi.org/10.1108/17410380810847927

Talib. (2017, November 21). Role of Industrial Sector in Economic Development of Pakistan -. Retrieved June 26, 2018, from https://talib.pk/article/role-industrial-sector-economic-development-pakistan

Tawfik Mady, M. (1991). The Effect of Type of Industry on Inventory Investments and Structure: The Egyptian Case. *International Journal of Operations & Production Management*, *11*(6), 55–65. https://doi.org/10.1108/01443579110002959

Upadhye, N., Deshmukh, S. G., & Garg, S. (2010). Lean manufacturing in biscuit manufacturing plant: a case. *International Journal of Advanced Operations Management*, *2*(1/2), 108. https://doi.org/10.1504/IJAOM.2010.034589

Van der Vorst, J. G. A. J., van Dijk, S. J., & Beulens, A. J. M. (2001). Supply Chain Design in the Food Industry. *The International Journal of Logistics Management*, *12*(2), 73–86. https://doi.org/10.1108/09574090110806307

White, R. (1993). An Empirical Assessment of JIT in U.S. Manufacturers. *Production and Inventory Management Journal*, *34*, 38–42.

White, R. E., & Prybutok, V. (2001). The relationship between JIT practices and type of production system. *Omega*, *29*(2), 113–124. https://doi.org/10.1016/S0305-0483(00)00033-5

Womack, James P., Jones, D. T., & Roos, D. (2007). *The Machine That Changed the World: The Story of Lean Production-- Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry* (Reprint edition). New York, NY: Free Press.

Zanoni, S., & Zavanella, L. (2005). Model and analysis of integrated production–inventory system: The case of steel production. *International Journal of Production Economics*, *93–94*, 197–205. https://doi.org/10.1016/j.ijpe.2004.06.018