

Lean principles, practices, and impacts: a study on small and medium-sized enterprises (SMEs)

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Abstract Lean as a business strategy is used to improve quality and service, eliminate waste, reduce time and costs, and enhance overall organizational effectiveness. Heightening challenges in competition in recent years have prompted many small and medium-sized enterprises (SMEs) to adopt lean to enhance firms' competitiveness. This paper attempts to present an all-inclusive study and it examines various factors associated with the implementation of lean in SMEs in the U.S. The findings suggest that most of SMEs have a relatively accurate understanding of lean concept and philosophy. The primary reasons to implement lean are mainly internal, including reduce cost, improve profit margin, improve utilization of plant/facility, and maintain competitive position. A hierarchical cluster analysis was conducted to investigate lean status. It was discovered that both advanced adopters and beginners of lean are discovered. ANOVA test results show that there exist quite significant differences in terms of the degrees of lean implementation in SMEs. Varied lean tools and programs have been applied and they are positively related with firms' performance. Lastly, the paper provides evidences that major lean barriers are encountered by SMEs regarding management or people related factors as well as key knowledge and know-how.

Keywords Lean manufacturing · Lean tools · Supply chain · Probability · SMEs

1 Introduction

Lean is an operational practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination (Holweg 2007). The concept of lean can be traced back to the 1960s, when the Japanese automobile manufacturer Toyota first introduced and implemented the Toyota Production System (TPS) which is identified as the "origin" of lean (Krafcik 1988). With its significant success, lean has become a popular business model for various global companies

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and it has become an integral part of the manufacturing landscape in the U.S. over several decades.

Lean is the identification and elimination of non-value added processes or “waste” as viewed by the customer. Material or information being stored, inspected, delayed, waiting in queues, and defects/errors do not add values. As a business strategy, lean is used to improve quality and service, eliminate waste, reduce time, and reduce total costs. The ultimate goal of a lean organization is to create a smooth and high quality process that is able to produce finished products and provide service to satisfy customers’ demand with no waste. Its link with superior performance and its ability to provide competitive advantage is well accepted among academicians and practitioners alike (Krafcik 1988; Pil and MacDuffie 1996; and Ward and Zhou 2006).

Intensified global competition, increased customer requirements, along with higher materials and energy costs in recent years have forced many companies to continuously modify and optimize their operations both at the strategic and tactical levels. The development and application of supply chain management (SCM) provide more room for lean, helping it to expand from a cross-functional to a cross-organizational approach to optimize business activities and results. SCM encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management. It also includes the crucial components of coordination and collaboration with channel partners, who can be suppliers, intermediaries, third-party service providers, and customers. Li et al. (2005) conceptualized and validated six dimensions of SCM practices, including, strategic supplier partnership, customer relationship, information sharing, information quality, internal lean practices, and postponement. In particular, they measured lean restrictively with items that include set up time, small lot size, and pull production.

Advancements in information technology and business analytics technologies provide unprecedented opportunities for designing, implementing, and expanding lean operations from global companies to small and medium-sized enterprises (SMEs). Many SMEs have become important players in large supply chain networks and they either voluntarily or have been forced to apply lean to gain and sustain competitive advantage. Small businesses are an important driving force behind the U.S. economy. According to the U.S. Small Business Administration (SBA), small businesses represent 99.7 % of all employer firms, make up half of all private sector jobs, and have generated 65 % of net new jobs over the past 17 years. Ferocious challenges in competition have prompted many SMEs to adopt lean to enhance the firms’ efficiency and competitiveness. With its proven success in large companies, lean has become more attractive to many SMEs in the country.

On the other hand, limitations in various external and internal aspects, such as financial and capital, knowledge and human resources, management concept and philosophy, and accessibility of lean tools and techniques, have restricted the development and implementation of lean in SMEs. Many small firms are not able to transform themselves to lean organizations toward creating the world-class companies. The transformation towards lean organization is filled with arduous challenges, most particularly with respect to understanding the real essence of lean concept and philosophy, and also to dealing with the cultural differences within the organization (Wong 2007). Management’s inability to respond and adapt to changes required by lean practices is widely considered to be the No. 1 issue. Lean requires new knowledge and cultural change during the transition and it should be applied comprehensively and holistically in principles and concepts (James 2006). Major Lean barriers are not tools and technologies, but the lack of understanding and supports from middle and senior management.

Lean practices in SMEs have a relatively short history, and a lot of important issues and areas are largely untouched in academic research. As very few studies regarding lean

SMEs have been done in the past, a thorough research needs to be carried out so as to gauge how small organizations in this country view it, adapt to it, and practice it. This study is the first attempt to provide a holistic view of lean practices in SMEs. The objectives of this research are three-fold. First, through a research questionnaire, we have investigated current lean practices in small and medium-sized enterprises (SMEs) in the US. Second, we have focused on providing first-hand knowledge on the status of lean implementation, discussing the outcomes of lean adoption, analyzing major benefits, and revealing factors that are capable to hinder or delay the process. Thirdly, we have examined the impacts of lean on SMEs and procedures that are needed to ensure a successful lean implementation. In general, the study provides a better understanding of lean strategies as they are used by small organizations. Furthermore, we present insights for designing and improving strategies to enhance the effectiveness of such small organizations.

The remainder of this article will proceed as follows. In Sect. 2, we provide a detailed review of related literature and highlight the main research issues of lean strategies in SMEs. In Sect. 3, we describe the research methodology employed in this study. Section 4 is devoted to an in-depth analysis on major research findings, including lean perception, driving forces of lean practices, lean implementation status, as well as major benefits and challenges experienced. Lastly, Sect. 5 concludes the entire study.

2 Literature review

Lean is most often associated with the reduction of wastes to ameliorate the impacts of variability and uncertainty of supply, demand, and time. Improving quality and service are the main goals of lean, as defective or products of poor quality or reliability should be considered “waste”. In an earlier work, Womack et al. (1990) studied the global automotive industry and used the term “Lean production” to describe the practices of leading automotive companies, which are considered far superior to those of other companies around the world. Lean production requires that not only should technical questions be fully understood, but existing relationship among different functional areas, such as research and design, engineering, human resources, marketing, and information technology, should be examined in depth, as should other factors external to the firm (Womack and Jones 1994). Karlsson and Ahlström (1996) developed a model that operationalized different principles in lean, with a focus on those that concern the work organization in the manufacturing part of a company. The model has been developed using available theory and has also been tried out in a clinical field study.

Principles of lean thinking have been widely accepted by many firms and have been applied quite successfully across many disciplines (Poppendieck 2002). Cua et al. (2001) studied the relationships between implementation of Total Quality Management (TQM), Just-in-Time (JIT), and manufacturing performance, which are regarded as key elements of lean. Shah and Ward (2003) developed measures for lean manufacturing and operationalized it as bundles of practices related to quality management, total preventive maintenance, and human resource management. They limited their analysis to four bundles that are oriented internally to reflect a firm’s approach to managing its manufacturing operation. Achanga et al. (2006) found that the success of lean implementation depends on four critical factors: (a) leadership and management; (b) finance; (c) skills and expertise; and (d) supportive organizational culture of the organization. Zhou et al. (2007, 2009) discussed mathematical models in which order quantity requirement and free shipping are used either as constraint or incentive to achieve economies of scale in the manufacturing/purchasing process and provided heuristic approaches to minimize and reduce total purchasing costs. Wong et al. (2009)

developed a collective set of key areas or factors leveled to be critical for the implementation of lean. These factors encompass a broad array of practices, ranging from product design, suppliers, tools and techniques, to employees, safety and ergonomics, and management and culture.

Tools and techniques are indispensable in lean implementation. Lean tools and techniques that are systematically applied can be instrumental in defining, evaluating, and attacking sources of inefficiency in specific ways (Wong et al. 2009). A variety of different lean tools and programs, such as value stream mapping (VSM), workplace organization (5S), changeover reduction (SMED), quality certifications (e.g. ISO), Kaizen, and Pull/Kanban, are available and they are useful in dealing with varied issues and circumstances. Liker (2004) argued that lean tools and techniques are urged to be used in an integrated way rather than implementing them in isolation.

Most researchers suppose that human resources (people) are essential to the implementation of lean, since people are often the key element in operations. In the classical TPS, employees are regarded as assets, and they are the ones who are going to solve problems and improve processes (Sharp et al. 1999). Womack et al. (1990) argued that employees are critical throughout the lean practices and they are the heart of the lean organization. It is believed that lean concept or philosophy should be shared by employees of all levels in the organization. Companies need to create regular lean training opportunities which enable them to have up-to-date knowledge and respond faster to changes in products and processes.

Management and culture is also considered an essential area and it is crucial for management to understand and provide ample support to apply lean in the organization. Some work revealed the role and importance of management during the lean implementation process. Worley and Doolen (2006) argued that management support plays a vital role in driving lean implementation. Communication and collaborations among employees at similar levels but from different functional areas are very important. Communication between senior management and employees is even more critical to ensure that the vision and mission of lean is attainable and shared throughout the company. A supportive culture and environment in an organization that brings employees to work, communicate and grow together is essential to make lean initiative successful. Recognition and rewards will serve as incentive and motivation for employee participation and continuous improvement (Little and McKinnis 2005).

The change from traditional practice to lean is challenging from both inside and outside. Some researchers categorized lean elements based upon the areas of implementation, such as internationally and externally oriented practices. Panizzolo (1998) divided the lean practice into six different areas. These areas include four internal oriented lean practices: *process and equipment*; *manufacturing, planning, and control*; *human resources*; and *product design*; and two external oriented lean practices: *supplier relationship* and *customer relationship*. The research presented in this paper revealed that many firms seem to have difficulty in adopting lean tools that deal with external relationships. Jain et al. (2010) argued that firms operate in global environments, deal with multiple suppliers and customers, are required to manage inventories in new and innovative ways, and are faced with possible channel restructuring. Wang and Zhou (2010) believed that the development of reverse supply chain management relies heavily on lean production and engineering that play crucial roles in the recycling, redesign, and reuse processes. These are among the main subjects of this research, and we aim to investigate the status of lean implementation of SMEs, analyze the influences of lean, and discover what changes are needed to ensure the success of lean in small organizations.

3 Research methodology

The main objective of this paper is to investigate the adoption of lean in SMEs. To achieve this, data was collected via a questionnaire survey. The survey method is the best data collection technique as it enables us to gather a larger amount of data and information from target respondents within a short period of time. Small and medium-sized businesses in various industries are our research population. The sample of organizations was obtained from different regional chapters of Association for Operations Management (APICS). APICS was chosen since it is the biggest professional association for operations and supply chain professionals, and its members include managers and owners of many small and medium-sized firms across the nation. A total of 200 small and medium-sized companies were randomly selected through APICS chapters in the Northeast region in the U.S. Then questionnaires were distributed through emails, which led to the website that hosted the survey questions. The personnel involved in the questionnaire were managers, managing directors, vice presidents of operations, and owners of the companies. They should be regarded as the most appropriate personnel who are likely to be the leaders in charge of lean implementations, if any, in the organizations. Since the project is focusing on exploring the current practices, needs and challenges of lean in small and medium-sized organizations in the U.S., the sample of the study included a variety of companies in manufacturing, logistics, distribution and retail industries. This selection is not only convenient but represents organizations that have experienced fast development and faced significant lean opportunities/challenges.

The survey instrument developed for this research included several major components, covering different interested aspects. The first part, “Company Profile”, measures respondents’ primary background information, including operating locations, type of industries, type of ownership, main products or service provided, number of employees, sales data, job title, etc. The second part, “Perceptions of Lean”, collects their understanding of lean concepts and philosophy. Questions in this part also try to find out the trigger factors or driving forces that are responsible in adopting lean in the firms. The last part, “Lean Implementation”, evaluates respondents’ overall assessment of their current practices of lean, lean tool and techniques used, areas and places applied, and leadership and commitment from management. Moreover, major benefits, limitations, and challenges found in the implementation process are identified.

Five-point Likert-type scales were used to measure responses to questions in the second and last parts of the survey. These scales provide adequate levels of discrimination among the choices given to target respondents. Potential respondents’ answers were measured with a five-point scale, anchored at, for instance, 5 “strongly agree”, 4 “agree”, 3 “neutral”, 2 “disagree”, and 1 “strongly disagree”. The application of these scales is an effort to force respondents to make an exclusive and decisive choice. In addition, this design of the survey instrument can also keep it short and help the respondents to answer them in less time.

A pilot study was included during the survey development process. Lean experts from both industries (3 practitioners) and academics (3 academicians) were consulted. The pilot survey was utilized to alter and eliminate some variables. Comments and feedbacks from these experts were examined and some modifications were made especially with respect to questionnaire readability. Majority of the comments from the pilot study were very positive and confirmed that the questionnaire was suitable for distribution.

Reliability tests were carried out to ensure that the questionnaire was reliable. Reliability measurement is an indication of the stability and consistency of the instrument applied. Cronbach’s Alpha was used to test the reliability. A minimum value of 0.60 was regarded

Table 1 Reliability and validity results on five areas

Areas	No. of items included	Cronbach's alpha	Items for deletion	KMO values
Lean perception	8	0.93	0	0.84
Lean drivers	13	0.95	0	0.78
Lean tools and programs	20	0.96	0	0.80
Lean benefits	14	0.98	0	0.91
Lean challenges	11	0.82	0	0.71

as acceptable in this research, as it is generally agreed that 0.60 is an appropriate threshold (Sakakibara et al. 1999). Further, construct validity test was achieved through principal components test. Kaiser-Meyer-Olkin (KMO) tests were employed to measure the sampling adequacy. A summary of the reliability and validity analysis is presented in Table 1.

It is observed that all the results of the elements in lean perception, lean drivers, lean practices, and lean benefits and challenges show very high internal consistency. Cronbach's Alpha values (Table 1, column 3) vary from 0.82 to 0.98, which are significantly greater than the threshold value of 0.60, and hence they are reliable. In the validity test results, KMO values of the five areas are varying from 0.71 to 0.91, all exceeding the minimum score of 0.50, demonstrating that all these areas and factors are valid. In summary, it can be concluded that all the areas of interests in the study are reliable and valid.

4 Research findings and discussions

We used a commercial website to create and store the survey. This enabled us to provide an online survey link to potential respondents. Initial emails were sent to 200 small and medium-sized companies. In the email, a general description of the research project, its purpose, and the URL link to the survey was provided. Follow-up emails were sent to these target companies after 2 weeks to remind the respondents to finish the questionnaire. Finally, a total of 45 responses were obtained. After initial screening, 34 of them were valid for analysis. As a result, the response rate was 17 %.

4.1 Company backgrounds

There is no universally accepted definition of an SME, even within the U.S. government. This situation reflects the relative nature of the “small” and “medium” size classifications, which can apply differently to firms in the manufacturing and service sectors. In recognition of these differences, we use technical thresholds, i.e. the number of employees and annual firm revenue, previously established by U.S. government institutions, including those of the U.S. Department of Commerce, the U.S. Small Business Administration (SBA), and the U.S. Department of Agriculture (USDA), as guidelines. In this research, we use SBA advocacy's “fewer than 500 employees” definition of SMEs across all sectors.

The first area of interest was the general background information of the respondents involved in the research. We summarized the key data obtained from the survey with respect to respondents' profiles in Table 2. These data include job title, type of industry, type of ownership, number of locations, number of years of lean implementation, and number of employees.

Table 2 General background information of the respondent companies

Job title in the company	No.	Percentage
Managers or executives	18	52.9 %
QA or QC personnel	7	20.6 %
Other	9	26.5 %
Type of ownership		
Private	28	82.4 %
Public	6	17.6 %
No. of employees		
Minimum	12	–
Maximum	521	–
Average	113	–
No. of operating locations		
1 to 3	31	91.2 %
4 to 6	0	0.0 %
7 and above	3	8.8 %
Type of industry		
Manufacturing	29	85.3 %
Service/distribution	5	14.7 %
Years of lean practice		
Less than 3 years	18	52.9 %
3 to 6 years	12	35.3 %
Above 6 years	4	11.8 %

In terms of the personnel involved in the study, approximately 53 % of the respondents hold managerial or executive positions, and around 21 % are in QA or QC positions. These respondents are believed to have the necessary experience and knowledge of their companies, especially on the implementation of lean. As for the type of ownership, private firms account for 82.4 % of the respondents, while public companies account for 17.6 %. Based upon governmental report, majority of SMEs are privately owned. Hence, these results are consistent with our expectation. In terms of the size of these companies, the smallest firm has 12 employees, the biggest company has a little over 500 employees, and the average number of employees of the respondents is 113. In addition, majority, or 91.2 %, of these respondent firms operate in less than 3 locations, while 8.8 % have more than 7 business locations. These results show that the samples involved in the study are clear representations of SMEs.

Other than the above background information, we also identified the respondents' operating industries. It is shown that manufacturing companies account for 85.3 % of the respondents, which include metal and chemical goods, machinery, electronic components, and pharmaceuticals. The rest of the respondents are in the fields of logistics, distribution, consumer service, etc. One of the major subjects of this study is to investigate the extent of lean implementation in the firms. To this end, we introduced a short question on the number of years of lean practice in these companies to gauge their degree of lean. Our results show that more than one third (35.3 %) of the respondents indicated that they have applied lean within the organizations from 3 to 6 years; more than half (52.9 %) of the respondent companies

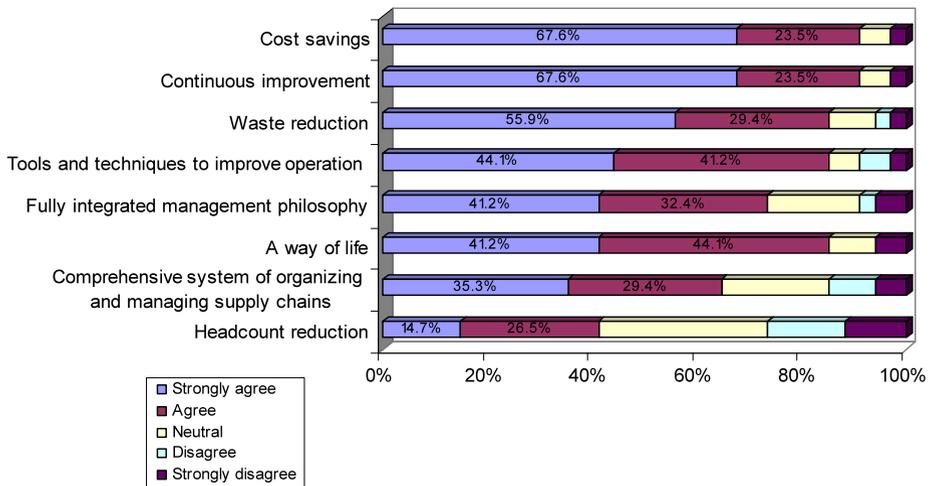


Fig. 1 Understanding of lean concepts and philosophy

admitted that they have less than 3 years of lean practices; and approximately one tenth (11.8 %) of the respondents indicated that they have more than 6 years of lean practices.

4.2 Perception and driving factors of lean

Understanding of lean concepts and philosophy is very important to an organization, and it can directly affect its lean decision, application, and results. To identify the perception of lean in SMEs, respondents were asked to indicate their understanding of lean from 8 aspects/questions. A five-point scale, ranging from “5 = strongly agree” to “1 = strongly disagree”, was used to measure their responses. Figure 1 graphically illustrates the results.

As can be observed, the top three variables, “cost savings”, “continuous improvement”, and “waste reduction”, represent the primary understanding of lean of the respondent companies. Majority of the firms either strongly agree or agree (greater than 85 %) that lean can be expressed by these elements. Moreover, a large number of the respondents indicated that lean can be regarded as “tools and techniques to improve operation” (85.3 %), “fully integrated management philosophy” (73.5 %), or “a way of life” (85.3 %). These findings imply that most SMEs have a relatively accurate and correct understanding of lean concept and philosophy.

In addition, approximately 65 % of the respondent firms agreed that lean is a “comprehensive system of managing supply chains”, 20.6 % did not think the relationship is strong, whereas approximately 15 % of the respondents indicated that lean is not directly associated with supply chains. This result is both interesting and important. A possible explanation of this phenomenon might be that due to varied reasons, many small businesses have not engaged in significant supply chain activities, and therefore have not considered lean as a systematic approach that could facilitate the coordination and collaboration among suppliers, manufacturers, distributors, and customers in the supply chain network.

Next, respondents were requested to indicate the major reasons to apply lean in their operations. Thirteen possible driving forces were given in the survey and the findings are presented in Fig. 2.

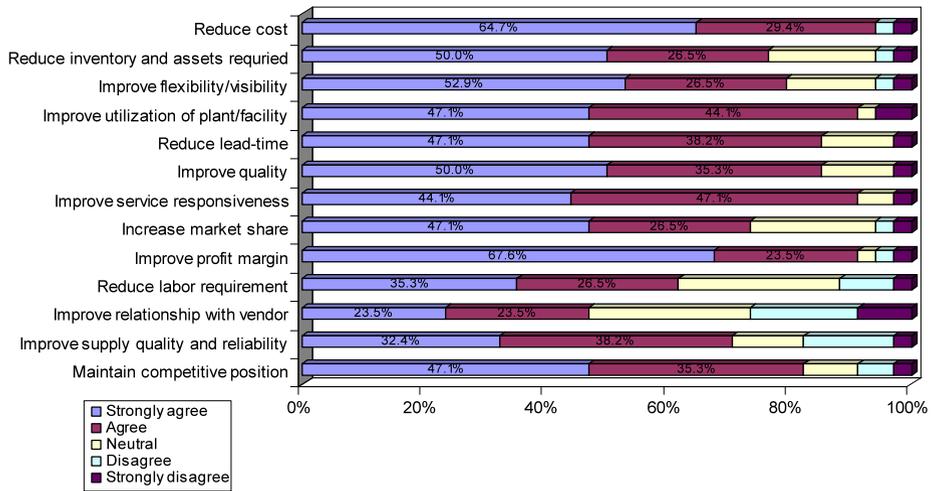


Fig. 2 Driving factors of lean implementation in SMEs

The biggest driving factor that influences the implementation of lean in SMEs is reduce cost, which represents more than 94 % of the respondents’ reasons (strongly agree plus agree) for lean adoption. This result is understandable since most of the respondent companies are in the manufacturing industry. Other primary drivers that lead to lean practices in SMEs include, improve utilization of plant or facility (91.8 %), improve service responsiveness (91.2 %), and improve profit margin (91.1 %). Moreover, it is also worth to note that maintain competitive position, with exhibits 82.4 % of the respondents, is another important reason for lean implementation in small companies.

It is interesting to see that neither improve relationship with vendor nor improve supply quality and reliability seem to be the main drivers for lean implementation in SMEs. In fact, Fig. 2 shows that only less than one third of the respondents strongly agree that improve relationship with vendor and improve supply quality and reliability are the causes to apply lean in their firms. These results are not really surprising. Panizzolo (1998) argued that many companies seem to have difficulty in adopting lean tools that concern with external relationships such as with suppliers. These results are also consistent with our earlier analysis on Lean Perception, which revealed that fewer respondents believed that lean can help supply chain management. Based upon the above, we can state that although supply chain management has drawn significant attention and experienced dramatic growth in larger companies, SMEs have relatively limited involvement in supply chain activities and they tend to use and isolate lean from the supply chain context.

4.3 Lean implementation status

To accurately assess the lean implementation status, a list of 20 lean tools and programs were included in the survey. Respondent companies were asked to indicate which tools have been implemented and their level of adoption in practices. A five-point scale was used in the questions with “5 = very high level of implementation” and “1 = very low level of implementation”. Table 3 presents the mean values and standard deviations of these tools and programs for all respondents.

Table 3 Lean tools and programs applied, all respondents as one group

Lean tools and programs applied	Variables		
	Rank	Mean	STD
Workplace organization (5S)	1	2.91	1.33
Quality certifications (e.g. ISO)	2	2.85	1.86
Work standardization	3	2.82	1.09
Visual management	4	2.82	1.29
Continuous improvement program	5	2.79	1.30
Changeover reduction (SMED)	6	2.62	1.28
Process mapping	7	2.59	1.40
Value stream mapping (VSM)	8	2.53	1.44
Cellular layout	9	2.50	1.29
Energy management	10	2.50	1.26
Error proofing (Poka yoke)	11	2.47	1.31
Kaizen events	12	2.47	1.35
Pull/Kanban	13	2.44	1.33
PDCA problem-solving	14	2.44	1.35
Environmental management	15	2.44	1.33
Just-in-time (JIT)	16	2.26	1.21
Total productive maintenance (TPM)	17	2.26	0.99
Benchmarking	18	2.24	0.99
One piece flow	19	2.15	1.21
Six Sigma	20	1.97	1.17

As shown in Table 3, among all the lean tools and programs, workplace organization (5S) is the top-ranked lean tool applied in SMEs with a mean value of 2.91, and a standard deviation of 1.33, followed by quality certifications and work standardization, with mean values of 2.85 and 2.82, and standard deviations of 1.86 and 1.09, respectively. Aside from the top three tools, other widely applied, highly-ranked lean tools and programs include, for instance, visual management, continuous improvement program, and changeover reduction (SMED). The relative high mean scores of these tools indicate that SMEs seem to emphasize on using various lean tools to standardize, improve, and optimize internal operating procedures. Reducing wastes and costs are the obvious priorities of these firms.

An interesting finding on lean implementation status is Six Sigma. With a mean score of 1.97, Six Sigma is the lowest ranked lean tool, indicating a much lower-than-average implementation level among the respondent companies. This result seems unintuitive at the beginning since majority of the respondents are manufacturing firms. However, as a mature and systematic lean tool, Six Sigma requires a high level of knowledge, expertise, and organization-wide collaboration. We believe that a possible explanation of the low degree of implementation of Six Sigma could be that many SMEs are still early lean adopters and they might lack the ability to fully implement comprehensive lean tools such as Six Sigma in their operations.

Finally, a very important overall finding is that the mean scores of the 20 lean tools and programs have relatively small values, ranging from 1.97 to 2.91 (Table 3, column 3) with grand average mean score of 2.50, implying a relatively low level of implementation among these respondent firms. To further investigate the application status of lean tools and

Table 4a Lean tools and programs applied with hierarchical cluster analysis, cluster one

Cluster one: Lean group ($n = 10, 30\%$)			
Lean tools and programs applied	Variables		
	Rank	Mean	STD
Workplace organization (5S)	1	4.40	0.66
Visual management	2	4.30	0.46
Process mapping	3	4.20	0.75
Value stream mapping (VSM)	4	4.20	0.75
Kaizen events	5	4.10	0.70
Continuous improvement program	6	4.00	0.77
Quality certifications (e.g. ISO)	7	3.90	1.51
Error proofing (Poka yoke)	8	3.80	0.87
Work standardization	9	3.70	0.78
Changeover reduction (SMED)	10	3.60	0.66
Pull/Kanban	11	3.60	1.20
PDCA problem-solving	12	3.60	1.28
Cellular layout	13	3.60	1.11
One piece flow	14	3.40	1.20
Environmental management	15	3.20	1.33
Total productive maintenance (TPM)	16	3.10	0.70
Benchmarking	17	3.10	0.83
Just-in-time (JIT)	18	3.00	1.18
Energy management	19	2.90	1.14
Six Sigma	20	2.20	0.87

programs and identify if there is any difference among the respondent companies, we carried out cluster analysis.

Respondent companies were segmented into three groups, namely, “Lean group”, “Somewhat lean group”, and “Not lean group”. Hierarchical cluster analysis was applied to study the mean values of the 20 lean tools and programs via squared Euclidean distance between these variables. Ward’s method was applied to optimize the minimum variances among clusters. Comparisons on the mean values and standard deviations were conducted among these groups. Tables 4a to 4c provide a summary of the results of the cluster analysis.

As a result of the cluster analysis, approximately 30 % of the respondents (10 firms) were identified as lean companies. These respondent firms have high mean values for all lean variables, representing a high degree of implementation of lean tools and programs in practices. As illustrated in Table 4a (column 3), the mean values of lean tools vary from 2.20 to 4.40, which are significantly higher than those in Table 3 (column 3), where the cluster analysis was not employed. Specifically, for the companies in the lean group, workplace organization (5S) is the most applied lean tool with the highest value of 4.40, indicating a quite substantial level of implementation. Other noticeable lean tools and programs that received high mean values include visual management, value stream mapping (VSM), and Kaizen events, with respective mean scores of 4.30, 4.20, and 4.10. These results demonstrate that lean firms tend to emphasize on the overall process effectiveness and efficiency.

The second group was in the middle, and they were organizations that could move from an early adoption phase to wide applications in various areas. Companies in this group made

Table 4b Lean tools and programs applied with hierarchical cluster analysis, cluster two

Cluster two: Somewhat lean group ($n = 13, 38\%$)			
Lean tools and programs applied	Variables		
	Rank	Mean	STD
Quality certifications (e.g. ISO)	1	3.46	1.82
Energy management	2	3.15	1.03
Continuous improvement program	3	3.08	0.73
Work standardization	4	3.00	0.78
Environmental management	5	2.92	1.00
Workplace organization (5S)	6	2.85	0.66
Visual management	7	2.85	0.66
Changeover reduction (SMED)	8	2.69	1.20
Cellular layout	9	2.69	0.82
PDCA problem-solving	10	2.62	0.92
Just-in-time (JIT)	11	2.54	1.08
Error proofing (Poka yoke)	12	2.46	0.93
Pull/Kanban	13	2.38	0.92
Process mapping	14	2.38	0.92
Total productive maintenance (TPM)	15	2.38	0.74
Kaizen events	16	2.31	0.82
Value stream mapping (VSM)	17	2.23	0.89
Benchmarking	18	2.23	0.70
Six Sigma	19	2.23	1.31
One piece flow	20	2.08	0.62

up approximately 38 % of the sample. Specifically, 13 firms were classified as “Somewhat lean”, which is the largest group, with moderate mean scores. As shown in Table 4b, quality certifications is the lean tool that received the highest mean value of 3.46, whereas one piece flow is the one that had the lowest mean score of 2.08. Other lean tools and programs that enjoy a moderate level of adoption include energy management (3.15), continuous improvement (3.08), and work standardization (3.00). Companies in the transition phase tend to rely on external available standards such as International Organization for Standardization (ISO) to quantify and improve lean practices within the firms.

Table 4c presents the results for the last cluster—Not lean group. The last group consisted of 11 “Not lean” firms, who were on the lower end of the scale and had not implemented lean nor had any formal integrated approach to lean. This group represented approximately one third of the respondents. As shown in Table 4c (column 3), these firms have low mean scores for all variables that vary from 1.09 to 1.82, therefore indicating rather limited lean practices. Work standardization, with highest mean value of 1.82, seems to be the focus of lean in these companies who might just start to implement lean in their operations. In addition, both workplace organization (5S) and Pull/Kanban received relatively higher mean values and ranked higher than others. These findings are consistent with our expectations, since these tools are simpler and easier to understand and implement and do not require significant time and financial commitment. The variable that received the lowest mean score in the last group (and also the Somewhat lean group) is one piece flow, with a value of 1.09 (and 2.08 respectively). One piece flow requires production moves from one stage to the

Table 4c Lean tools and programs applied with hierarchical cluster analysis, cluster three

Cluster three: Not lean group ($n = 11, 32\%$)			
Lean tools and programs applied	Variables		
	Rank	Mean	STD
Work standardization	1	1.82	0.72
Changeover reduction (SMED)	2	1.64	0.98
Workplace organization (5S)	3	1.64	0.88
Pull/Kanban	4	1.45	0.89
Visual management	5	1.45	0.66
Benchmarking	6	1.45	0.66
Six Sigma	7	1.45	0.99
Process mapping	8	1.36	0.64
Value stream mapping (VSM)	9	1.36	0.88
Total productive maintenance (TPM)	10	1.36	0.64
Continuous improvement program	11	1.36	0.64
Energy management	12	1.36	0.64
Error proofing (Poka yoke)	13	1.27	0.62
Just-in-time (JIT)	14	1.27	0.45
Cellular layout	15	1.27	0.62
Kaizen events	16	1.18	0.39
PDCA problem-solving	17	1.18	0.39
Quality certifications (e.g. ISO)	18	1.18	0.39
Environmental management	19	1.18	0.39
One piece flow	20	1.09	0.29

next stage one piece at a time, it benefits the manufacturer because there is no idle time between the units. In SMEs who have rather limited lean involvement, however, system-wide operations and control are difficult to achieve, and many decisions are largely based upon past experiences or common sense. This could be the reason why one piece flow has the lowest score in these two groups.

An important subject that is worth investigation is whether there was any significant difference among these three clusters with respect to their level of lean practices. To this end, one-way independent ANOVA test was conducted to gauge the clusters' validity and consistency with different mean values of lean tools and programs. The following hypotheses are developed: H_0 : All clusters' mean values are the same. H_a : All clusters' mean values are not the same.

Result of the ANOVA test showed F ratio = 116.06 and $p = 0.00$, indicating that the null hypothesis should be rejected and the mean scores of lean practices were significantly different across the three groups. Further, Levene's test was utilized to verify the equality of variances. The results of the Levene's test showed that all lean implementation tools and programs are not significant with $p > 0.05$. Hence, our ANOVA results are valid.

In summary, significant differences were identified among the clusters. Most importantly, differences were found in how they performed key lean tools and programs. As the results demonstrate, lean companies have statistically significantly higher level of applications of all lean tools and programs than not lean firms, which could be instrumental in promoting company efficiency and effectiveness.

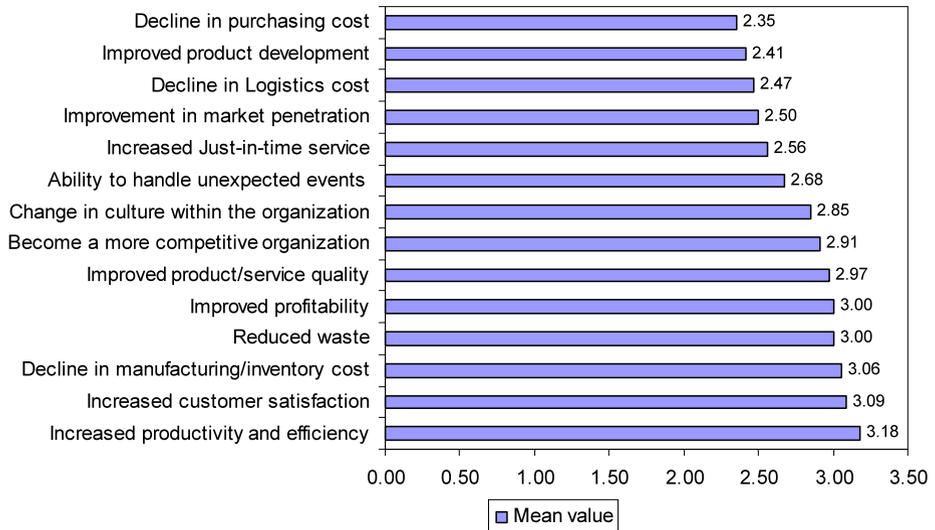


Fig. 3 Benefits of lean implementation

4.4 Benefits and challenges

Respondents were also asked to indicate the benefits of lean implementation in their firms. 14 possible benefits were included in the survey. Figure 3 presents a summary of the mean values of these benefits for all respondents.

It is clear to observe that all lean tools and programs have positive impacts on SMEs. As illustrated in Fig. 3, increased productivity and efficiency is the No. 1 benefit, which had a mean score of 3.18. Hence, there is a clear positive relationship between lean practices and productivity and efficiency of firms. Aside from this, increased customer satisfaction (mean score = 3.09) and decline in manufacturing/inventory cost (mean score = 3.06) are another two primary benefits brought by lean. On the other hand, decline in purchasing cost and improved product development seem to be the areas that do not benefit very much from the application of lean tools and programs in these firms. The low level of benefit of product development might be explained by the reality that many SMEs do not design their own products and therefore there is no formal product design system available.

Next, we are also interested in revealing the challenges or obstacles that may hinder or delay the lean implementation process in SMEs. Since the results of lean tools and programs showed noticeable differences among different groups, cluster analysis was also applied here to provide detailed insights. We used the same three groups, namely Lean, Somewhat Lean, and Not Lean, to examine the challenges or obstacles of lean practices in the firms. Table 5 provides a summary of the challenges that were faced during lean implementation for the three groups with differed lean experience.

The first group consisted of companies that have used rather limited lean tools in their practices. The five biggest challenges or obstacles faced by the lean beginners include: company culture changes, lack of time, backsliding to the old ways of working, lack of budgets, and lack of willingness from management. These indicate that major roadblocks of implementing lean in these firms are primarily “management”, “financial”, and “time” factors. Three of the top 5 obstacles are considered management or people related issues, including No. 1 company cultural changes, No. 3 backsliding to the old ways of working, and

Table 5 Challenges of lean implementation with hierarchical cluster analysis

Cluster one: Not lean group ($n = 11, 32\%$)			
Lean challenges	Variables		
	Rank	Mean	STD
Company cultural changes	1	4.55	0.69
Lack of time	2	4.27	0.79
Backsliding to the old ways of working	3	4.09	1.04
Lack of budgets	4	3.91	1.04
Lack of willingness from management	5	3.73	1.49
Employee resistance	6	3.64	1.29
Inadequate knowledge and know-how	7	3.36	1.21
Risk of disruption in operations	8	3.36	1.12
Difficult to quantify the value of Lean	9	2.82	1.54
Failure of past Lean projects	10	2.09	1.87
Need to integrate other organizations	11	2.09	1.38
Cluster two: Somewhat lean group ($n = 13, 38\%$)			
Lean challenges	Variables		
	Rank	Mean	STD
Company cultural changes	1	3.85	0.69
Inadequate knowledge and know-how	2	3.69	1.18
Lack of time	3	3.62	0.87
Backsliding to the old ways of working	4	3.62	0.77
Lack of willingness from management	5	2.92	0.95
Lack of budgets	6	2.92	1.04
Employee resistance	7	2.85	0.55
Risk of disruption in operations	8	2.85	0.69
Difficult to quantify the value of Lean	9	2.85	0.80
Need to integrate other organizations	10	2.62	0.87
Failure of past Lean projects	11	1.92	0.86
Cluster three: Lean group ($n = 10, 30\%$)			
Lean challenges	Variables		
	Rank	Mean	STD
Backsliding to the old ways of working	1	3.40	1.26
Company cultural changes	2	3.20	1.14
Employee resistance	3	2.90	1.37
Need to integrate other organizations	4	2.90	1.20
Inadequate knowledge and know-how	5	2.70	1.16
Lack of time	6	2.60	0.84
Failure of past Lean projects	7	2.30	1.16
Lack of willingness from management	8	2.10	0.88
Lack of budgets	9	2.10	0.88
Risk of disruption in operations	10	2.00	0.67
Difficult to quantify the value of Lean	11	1.80	0.63

No. 5 lack of willingness from management. Clearly, lean initiatives and commitment are the toughest issues for SMEs to start lean.

For the second group of companies that have moderate level of lean practices, the top five biggest challenges are company cultural changes and inadequate knowledge and know-how, followed by lack of time, backsliding to the old ways of working, and lack of willingness from management. These results imply that lean concept and philosophy fundamentally transform a firm's operations, which lead to shocking changes in an organization's culture. This is normally considered as the most challenging change and it is happening in the initial phases in implementing lean. Hence, lack of understanding of lean is the primary hurdle that many firms must overcome. As firms have become more engaged in lean practices, management must have adequate knowledge of a variety of lean tools, techniques, and programs to ensure proper and smooth applications.

Major challenges for the last group—lean firms, were also identified. As observed in Table 5, backsliding to the old ways of working topped the list of lean obstacles, followed by company cultural changes, employee resistance, need to integrate other organizations, and inadequate knowledge and know-how. Reverting to the old ways of working may due to the reason that lean initiatives need additional work and responsibilities, hence employees could resist these changes. After a considerable level of lean implementation, organization-wide restructuring might be necessary to further reduce waste and costs. The resistance of lean can come from the thoughts that some positions could be eliminated as they are considered to be the ones that do not add values to the firm. Nevertheless, these are still management or people related factors that could pose serious challenges to lean practice. It is very important to create a lean culture that can be shared across the entire organization even in lean companies. Ample supports and active involvement ranging from upper management to individual employees are all crucial to the success of lean implementation.

An interesting finding from the analysis is that there is a need to integrate other organizations is the No. 4 factor that challenges the lean group, while it has a much lower rank in the first two groups (ranked the last in the Not lean group, and ranked 10th in the Somewhat lean group), where companies have either very limited or moderate lean activities. These differences among the groups reflect the natural lean adoption process. As companies become more advanced in this area, lean tends to expand and go beyond the four walls of individual companies and is practiced in a wider scope involving supply chain partners, such as suppliers, distributors, and customers. Lean initiatives should not be implemented in isolation within single firms. Rather, a lean supply chain enables a better understanding of the components, dependencies, and risks which enable improved management of material, financial, and information flows. It also helps to identify opportunities to continuously improve business process and performance in the constantly changing environment.

Finally, to explore the significance of differences among means of these clusters with regard to the lean obstacles, we continued to use ANOVA test. Again, the result for all lean obstacles showed that $p < 0.05$, which indicates a significant difference of means scores of lean challenges across the three groups. Moreover, result of Levene's test ($p = 0.26 > 0.05$) showed that the variances for each group are relatively equal.

5 Conclusion

The primary objective of this paper is to enhance our understanding of lean practices in small and medium-sized enterprises (SMEs) in the U.S. The study has provided important insights into the current status of lean and related implementation issues. Our results

demonstrate that most of the firms have a relatively good understanding of lean concept and philosophy. Majority of the firms regard lean as costs savings, continuous improvement, and waste reduction. It was also found that the main driving factors that encourage SMEs to implement lean are: cost reduction, improve profit margin, reduce inventory and assets required, improve utilization of plant/facility, and maintain competitive position.

To identify and evaluate the lean status of SMEs, various lean tools and programs, such as Kaizen, Kanban, value stream mapping (VSM), just-in-time (JIT), visual management, cellular layout, have been included in the study. Cluster analysis has been conducted to identify and classify the respondents into three groups to further assess the extent of lean practices. It is found that the respondent firms were segmented into Lean, Somewhat Lean, and Not Lean, each has about one third of the sample size. This is an important finding which reveals that the current lean practice in SMEs is quite diverse, ranging from advanced adopters to beginners of lean who are involved in sporadic usage of lean tools.

A variety of types of benefits resulted from lean have been found in the study. Majority of the respondents indicated that increased productivity and efficiency is the primary benefit of lean. Further, lean also helps to improve customer satisfaction and cut manufacturing/inventory cost. However, most respondent firms did not find significant benefit in the product development area, as many SMEs may not have such product development activities. Moreover, the study identified the main challenges or obstacles of lean practice. It is found that management or people related factors are the biggest roadblocks for the adoption of lean. Company cultural changes and employee resistance demonstrate that lean initiatives should be started from a correct understanding and attitude. In addition, adequate knowledge of lean tools and programs is required for its proper implementation by businesses.

Our study has provided a survey of implications for the research and practice of lean. The study has its limitations and its results were obtained based upon a survey that has a limited number of samples. While cost will continue to be a primary driving force for changes, leadership must question current assumptions and prepare themselves for potentially revolutionary changes in their way of thinking and operations. The fundamental theme of a lean enterprise is continuous improvement and evolution to the next best state of operations. Companies need to see where they stand next to the “Best in Class” in their industries so as to target improvements that match their overall business strategies.

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