Research Journal of Applied Sciences, Engineering and Technology 12(2): 169-182, 2016
DOI:10.19026/rjaset.12.2318
ISSN:2040-7459; e-ISSN: 2040-7467

Submitted: June 8, 2015 Accepted: August 5, 2015 Published: January 20, 2016

Research Article

The Key Success Factors for Lean Manufacturing versus Six Sigma

Ibrahim Alhuraish, Christian Robledo and Abdessamad Kobi
LARIS, ISTIA, University of Angers, Angers, France

Abstract: The aim of this study is to investigate and identify the key success factors of implementing lean manufacturing and six sigma in separate ways. The study applies a quantitative approach and statistical analysis to determine the results collected from the French industry. Findings revealed that there exist statistically significant differences in the level of importance between the implementation of lean manufacturing and six sigma across the common success factors such as culture change, communication and involvement of employees, among others. On the other hand, there were similarities in the degrees of importance regarding the common success including top management commitment, skill and expertise and linking method to supplier, etc. The findings can assist an organization to be more careful with the success factors of each method, in addition to helping them in determining the appropriate method that enables exploration between lean manufacturing and six sigma based on the capacity of an organization to apply the success factors. Literature reviews regarding comparison of key success factors of lean manufacturing and six sigma had not been tested earlier, which have been considered in this study.

Keywords: Key success factors, lean manufacturing, six sigma, quality tools, statistical test

INTRODUCTION

Lean manufacturing is considered as a manufacturing philosophy which is adopted by companies to ensure that the costs involved in production are reduced and unnecessary wastes are eliminated from the production mechanism (Wilson, 2010). On the other hand, six sigma is concerned with the identification as well as elimination of the defects in the business mechanisms and processes by paying attention to the performance attributes that are considered critical for customers (Breyfogle III, 2003). Many companies carry out research today in order to achieve the best performance through implementing lean manufacturing and six sigma. Implementation of lean manufacturing and six sigma have motivated many industries to improve quality, improve productivity, reduce cost and customer satisfaction, although there are many industries that often fail to implement either lean (Scherrer-Rathje *et al*., 2009) or six sigma (Chakravorty, 2009), or combination of these two methods (Antony, 2011). Therefore, this study aims to identify the factors that are essential to successful implementation of lean manufacturing and six sigma. From the literature review, it is evident that there exist many common factors between lean manufacturing and six sigma that lead to successful implementation and these factors include communication, culture change, top management commitment, etc. Thus, these common factors between lean manufacturing and six sigma may or may not have identical degree of importance between lean manufacturing and six sigma. In order to verify that, a survey has been constructed in this study to make a comparison between these methods across the identical success factors between lean manufacturing and six sigma. These factors had been evaluated by experts in domain of lean manufacturing and six sigma or in function responsible for quality with their organization in order to distinguish the success factors of each method and to identify the priority of success factors of each method for lean manufacturing and six sigma. Therefore, the purpose of this study is to compare the common success factors between lean manufacturing and six sigma.

This study investigates the key success factors for implementing lean manufacturing and six sigma in separate ways. The findings revealed that there are statistically significant differences in the level of importance between implementing lean manufacturing and six sigma across the common success factors such as culture change, communication and involvement of employees, etc. Furthermore, a number of similarities regarding the common success factors between lean manufacturing and six sigma methodologies were found such as top management commitment, skill and expertise, linking method to supplier, etc. According to Andersson *et al*. (2006), there exist a number of important issues concerning similarities as well as differences amongst the lean and six sigma methods, which have not yet been discovered. Hence, the study provides an assessment of the comparison of the key success factors underlying both the methods of lean as

Corresponding Author: Ibrahim Alhuraish, LARIS, ISTIA, University of Angers, Angers, France

well as six sigma, which might be helpful for the companies to decide upon the method to be adopted depending on their organizational needs. Moreover, there is a necessity to consider the key success factors underlying each of the methods, which would assist in deciding the ability of the companies to implement the success factors within their organizational.

The paper has been organized as follows: After introduction, the literature review concerning the key success factors of lean versus six sigma that presented in the second section. The research method used has been discussed in section three. The fourthly section, we present, the result and the discussion of the study finding. This is follow, in section five, by the comparison between lean manufacturing and six sigma across the success factors. Finally, the main conclusion as well as the future research.

LITERATURE REVIEW

The basic reason behind the transfer of the concepts of six sigma and lean manufacturing to other organizations is the success they have achieved in organizations such as Motorola and Toyota (Andersson *et al*., 2006). The authors observed a number of critical success factors for six sigma that have been highlighted more frequently by other researchers (Antony and Banuelas, 2002; Coronado and Antony, 2002; Antony *et al*., 2005; Kwaka and Anbari, 2006; Gamal Aboelmaged, 2010; Antony, 2011; Brun, 2011; Zailani and Sasthriyar, 2011) that play a crucial role in successful implementation of six sigma. These factors such as top management involvement and commitment, linking six sigma to suppliers, linking six sigma to customer, etc. Since taking these factors into consideration enable the company to acquire the suitable plan of implementing six sigma (Kumar *et al*., 2007). Similarly these factors as well play a key role in the achieving of the lean manufacturing being successful due to the fact that most of the success factors play an important role in the implementation of lean manufacturing. As lean and six sigma complement each other (George, 2002; Breyfogle III, 2003; George, 2003; Arnheiter and Maleyeff, 2005; Gamal Aboelmaged, 2010; Antony, 2011; Snee, 2010; Prieto-Avalos *et al*., 2014)

Top management commitment and support consider the critical success factor of implementing either lean (Näslund, 2008; Scherrer-Rathje *et al*., 2009), or six sigma (Antony and Banuelas, 2002; Näslund, 2008; Chakravorty, 2009). Cultural change in employees attitudes toward quality and the influencing as well as restructuring of organizations are among the importance of the involvement of top management in the implementation of the six sigma (Henderson and Evans, 2000). The commitment made by the managers helps the employees to gain an understanding of the projects associated with lean (Scherrer-Rathje *et al*., 2009). Commitment and involvement of highest level of management is the topmost concern in development of organizations.

Linking either six sigma or lean to suppliers. The core reason behind the successful incorporation of the suppliers within six sigma is the ability of the suppliers in six sigma to gather support from topmost managerial levels in the supplier firms. Under the philosophy of six sigma, the most helpful way to lessen variability amongst the suppliers is to have lesser suppliers, who have high levels of sigma performance abilities (Coronado and Antony, 2002). Lean also applies along the company's supply chain network, consequently, there is waste reduction, as well as, increased organizational and supply chain communication (Scherrer-Rathje *et al*., 2009). There is an utmost need to correlate lean with the suppliers, since it is regarded as a critical success factor (Keller *et al*., 1991). It is necessary to decrease costs and wastages so as to ensure the success of lean manufacturing. This can be achieved by creating a relation amongst the suppliers and the manufacturers.

Linking either six sigma or lean to customers. During the process of implementing six sigma, there is an utmost need to consider the customers in the process, as they are regarded as one of the key players affecting the growth of organizations. Recognition of factor such as 'Critical To Quality' (CTQ) is essential to link six sigma with the customers (Antony and Banuelas, 2002; Coronado and Antony, 2002). In the process of lean manufacturing, customers are the ones who determine the value stream. Hence, the company must be able to recognize the requirements of the customers and must arrange the activities that would make the products available to customers (Wilson, 2010; Čiarnienė and Vienažindienė, 2012).

Linking either six sigma (Henderson and Evans, 2000; Coronado and Antony, 2002; Wyper and Harrison, 2000), or lean (Shah and Ward, 2003), to humane resources is necessary to ensure that the human resources employed in an organization work collectively towards the achievement of organizational goals. It is essential to link both methods to human resources in order to facilitate implementation, facilitate culture change, sustain the result and achieve a respectable behavior from the employees and concerned human resources associated with the organization.

Education and training consider one of success factors within six sigma (Henderson and Evans, 2000; Kwaka and Anbari, 2006; Näslund, 2008; Brun, 2011). Six sigma method own structure of training such as master black belt, black belts and green belt that cooperative to make effective implementation of supporting to increase company performance (George, 2003). It is requiring training workers the principles of lean as well to facilitate the implementation of lean

(Pingyu and Yu Yu, 2010) Education and Training is considered as one of the success factors for lean method (Näslund, 2008; Rose *et al*., 2014). In order to ensure that the employees are able to manage and implement either lean or six sigma, in an appropriate manner, it is necessary that they receive quality training and possess essential education qualifications to carry out the process of implementation and to increase their expertise and learn to make decisions using their own understanding.

Skills and expertise possessed by the employees are considered critical success factors for lean manufacturing and six sigma (Näslund, 2008). The level of skills and competencies amongst the employees in an organization, determines the organizational ability to incorporate six sigma. Six sigma techniques have a wider application and required specific skills, creativity and training. There exists a wider scope and application of six sigma; hence, there it requires particular set of skills, training as well as creativity (Antony, 2004; Gamal Aboelmaged, 2010). The higher the level of skills and competencies possessed by employees concerned with implementation of six sigma, the higher are the chances of success (George, 2003). Success of lean as well, is dependent upon the level of problem solving skills possessed by employees. In addition, skills and competencies acquired by the employees would help in generation of a plan regarding improvement in process and reduction of wastes (Bhasin and Burcher, 2006; Scherrer-Rathje *et al*., 2009; Wilson, 2010). Human skills and expertise is very important for the success of lean manufacturing (Achanga *et al*., 2006).

Understanding the tools and techniques consider one of the success factors within six sigma (Coronado and Antony 2002; Kwaka and Anbari, 2006; Näslund, 2008), or lean (Näslund, 2008; Scherrer-Rathje *et al*., 2009; Wilson, 2010). It is necessary to ensure that the tools and techniques associated with lean or six sigma are understood in a comprehensive manner. In addition, the technique of six sigma supported in the elimination of the defect related to quality and promotes improvement of performance. Furthermore, six sigma is considered to be occupying a specific responsibility in the organization, which is based on a narrow approach (Snee, 2010). Six sigma incorporates a wider range of tools and techniques comprising DMAIC, SPC, process capability analysis and root cause analysis among others, 2006. On the other hand, Lean aim to eliminate the wastage that includes various tools such as value stream analysis, 5S, total productive maintenance and kaizen among others that support to add value. We make a modification to this factor to be "understand the tools and techniques within method to white-collar worker and blue collar worker" for lean manufacturing and six sigma methods. In order to identify whether there are a different levels of importance between lean manufacturing and six sigma across understanding the tools and technique.

The communication process can be improved by establishing a mechanism that can be employed in helping the top management to get feedback from their employees, to ensure that employees accept change and to overcome resistance. Communication among the team members concerned with implementation of either six sigma (Coronado and Antony, 2002), or lean (Bhasin and Burcher, 2006; Manotas Duque and Rivera Cadavid, 2007; Scherrer-Rathje *et al*., 2009) is vital as proper communication significantly contributes towards the achievement of organizational success. Studies by Flynn *et al*. (1994), made it clear that open communication with customers help in monitoring the customers' requirements as well as in helping to identify the necessary improvements if the customers' requirements are not being met.

Cultural change plays a major role in determining the success rate of implementing six sigma (Coronado and Antony, 2002; Antony *et al*., 2005;Kwaka and Anbari, 2006) or lean (Achanga *et al*., 2006; Bhasin and Burcher, 2006; Wilson, 2010). Culture change requires supporting from the upper level management for providing a guideline to employees. Employees working in an organization need to possess a positive attitude towards solving problems and reducing time to ensure that the defect and wastes are eliminated.

Linking either six sigma (Coronado and Antony 2002; Brun, 2011), or lean (Bhasin and Burcher, 2006; Scherrer-Rathje *et al*., 2009), to business strategy is potential reason why either lean or six sigma need be incorporated into business strategy. It allows the organization to ensure that the business operations are efficiently conducted and are able to meet and surpass customer requirements.

According to Huq *et al*. (2010), there are various impacts of employee involvement such as decrease in ambiguity in the role of the worker, empowerment of the worker, as well as elimination of cultural resistance. Employee involvement is very important factors for effective implementation of six sigma (Hahn *et al*., 2000; Arnheiter and Maleyeff, 2005), as well as lean manufacturing (Scherrer-Rathje *et al*., 2009; Hibadullah *et al*., 2014; Rose *et al*., 2014), there is a need to involve the employees in the process of implementing lean, since it plays a crucial role in the determination of success.

There is an essential to reward the employees who are associated with implementation of the lean as well as six sigma. To ensure that the organization is able to effectively implement lean (Åhlström, 1998; Scherrer-Rathje *et al*., 2009), or six sigma (Ho *et al*., 2008). Reward encourages the employees in the organization to participate in projects that lead to improve quality and sustain results.

Consultant participation is important factor that support to the development of organizational goals and facilitates the implementation of lean (Scherrer-Rathje *et al*., 2009). As well for six sigma (Wiklund and

Wiklund, 2002). Consultant participation is known to support the activities and aid the implementation lean and six sigma, which bring about continuous improvement.

Antony and Banuelas (2002), reported that six sigma, which is a project driven methodology, requires that each team member should be skilled in project management so as to meet deadlines as the project progress. Various studies had highlighted 'project management skills' as success factors in the implementation of six sigma (Coronado and Antony, 2002; Kwaka and Anbari, 2006; Brun, 2011). Project management skills among the employees concerned with the implementation of Lean is necessary in ensuring that wastages in the process of implementation are minimized. Therefore, project management skills has been added as a success factor for lean manufacturing, also due to the desire to compare between lean and six sigma in terms of success factors.

The factors that follow were not compared between lean manufacturing and six sigma due to the fact that each of the methods have characteristics unique to either lean or six sigma but not both. For instance, six sigma has belt system whereas lean manufacturing does not. Belt system considered as a key success factor for the six sigma implementation and these include belt categories such as green belt, black belt, master black belt and champion, the implementation of belt mechanism enables the organization in the implementation of the six sigma for the achievement of success and all the belt mechanism have the responsibility of the development of six sigma within the organization (George, 2003; Kwaka and Anbari, 2006; Taghizadegan, 2010). On the other hand, leadership is considered as a major success factor in the implementation of lean (Dora *et al*., 2013). Success of lean manufacturing largely depends upon the leadership qualities possessed who train the employees regarding implementation of lean by employees implementing lean. Leaders working as professionals in the organization must take necessary steps to ensure that lean program is incorporated within an organization in achieve progress and success lean implementation (Dombrowskia and Mielkea, 2013).

Kaizen team is one of the lean technique which an important factor that assists in the enhancement of performance, which consequently affect the work in the improvement of lean projects rapidly with the organizations (Radharamanan *et al*., 1996; Scherrer-Rathje *et al*., 2009; Rahani and Al-Ashraf, 2012).

Project prioritization and selection, reviews and tracking selection of an appropriate project with the purpose of implementing six sigma can be considered as an important factor that would ensure early success for the organization (Antony, 2004). Selection of appropriate six sigma project depends on a number of criteria. These can be considered as an assessment of the Voice Of Customers (VOC), Defect per Million Opportunity (DPMO) and cost of poor quality, among others (Coronado and Antony, 2002; Gamal Aboelmaged, 2010).

By monitoring the progress and evaluation of the performance, an assessment of the lean progress would ensure that the implementation of lean is successful (Scherrer-Rathje *et al*., 2009; Pingyu and Yu Yu, 2010). Furthermore, monitoring of the progress would enable the organization to ensure that the project is implemented on a timely basis and in a sequential manner to indicate progress as well as to assess the effectiveness of the different changes (Åhlström, 1998; Manotas Duque and Rivera Cadavid, 2007; Pingyu and Yu Yu, 2010). Continuous monitoring and evaluation leads to understanding the current status and ensures that there is effective implementation of lean. Therefore, there should be evaluation of scheduling, material handling, employees, as well as, work processes.

METHODOLOGY

An online survey was the research instrument used in this study. The initial email was sent to 173 enterprises engaged in different type of industries in France. The survey was only dispatched after conducting a pilot study. The pilot study involved two experts on lean manufacturing and six sigma. Relying on the experts' advice an additional question was inserted in the survey and some minor changes were made to the survey. Altogether, 33 experts in quality and excellence completed answering the survey. The response rate was 19%. The objective of the data collection was the comparison of implementing lean manufacturing and six sigma methods across identical success factors. In order to identify the key success factors of implementing each method in France, each of these factors was measured within a five-point likert scale to indicate the important factors of implementing each method (lean manufacturing, six sigma). Respondents had the following five choices for answering each success factors follows; 1 = Unimportant, 2 = Slightly, important, 3 = Important, 4 = Very important, 5 = Critical. Critical was coded to be equal to five points, whereas unimportant was coded to one point. Each expert was asked twice for the same success factors, each for lean manufacturing and for six sigma. Participants were also asked an open question to add any additional success factors that they believe are critical to the successful implementation either for lean manufacturing or six sigma. Since dependent variable was measure on an ordinal scale, a statistical analysis was conducted by Wilcoxon signed ranks test to support whether there are significant differences or not between lean manufacturing and six sigma across the

Table 1: The result of Cronbach's alpha values for each key success factors lean and six sigma

Lean success factors	Cronbach's Alpha	Six sigma success factors	Cronbach's Alpha
Top Management commitment and support	0.851	Top management commitment and support	0.952
Involvement of employees	0.848	Linking six sigma to customers	0.951
Linking lean method to suppliers	0.859	Involvement of employees	0.950
Education and training	0.849	Linking six sigma method to suppliers	0.954
Communication	0.854	Education and training	0.948
Linking lean Method to the business strategy	0.844	Communication	0.948
Consultant participation	0.875	Linking six sigma Method to the business strategy	0.951
Understanding the tools and techniques within lean method to the employees that perform job in shop floor	0.837	Consultant participation	0.957
Understanding the tools and techniques within lean to the employees that perform job in an office	0.833	Understanding the tools and techniques within six sigma to the employees that perform job in shop floor	0.949
Cultural change	0.829	Understanding the tools and techniques within six sigma to the employees that perform job in an office	0.950
Monitoring and evaluation of performance	0.840	Cultural change	0.949
Skills and expertise	0.845	Project prioritization and selection, reviews and tracking	0.948
Leadership	0.833	Skills and expertise	0.952
Kaizen team	0.851	Belt system	0.955
Reward system	0.839	Linking Six Sigma to human resources	0.950
Linking lean to customers	0.846	Reward system	0.954
Linking lean to human resources	0.833		
Project Management skills	0.839		

identical success factors. SPSS version 20 was used to analyze the results. The internal consistency and reliability consistency for the success factors variables in the survey was tested using Cronbach's alpha coefficient. Cronbach's alpha coefficient tests the internal reliability consistency in a research instrument (Nunnally, 1978). In Table 1, Cronbach's alpha reliability coefficient was conducted to determine the reliability of the questionnaire. The result of Cronbach's alpha value was 0.85 for the success factors of implementing lean manufacturing whereas the value for the implementation of six sigma was 0.95. These indicated the strong reliability data collected from the survey. Furthermore, the results from factor analysis values of the Kaiser-Meyer-Olkin were 0.602 for success factors of implementing lean manufacturing, 0.806 for success factors for implementing six sigma and zero significance of Bartlett's tests for lean and six sigma, indicating that the variable met the reliability and validity requirements of the analysis. This further indicated that the results were acceptable.

The study executed investigations such as general profile of the organization, type of industry, age of companies, respondent's positions, number of employees, duration (in terms of years) for implementing the methods. This involved the investigation of the implementation of lean manufacturing and six sigma and whether methodologies lean manufacturing, six sigma or both are implemented as well as the reasons for not implementing both methods at the same time, tools and techniques of lean and six sigma and the success levels of implementing lean manufacturing and six sigma in French industry.

RESULTS AND DISCUSSION

The result presented in this study is of survey-based study on key success factors of the implementation of lean manufacturing and six sigma that were obtained from respondents from thirty three companies. Majority of the respondents 48.8% were quality managers, 18.2% of the respondents were consultants, 9.1% of respondents were project leaders, 6.1% of respondents were general managers and 12% of respondents were other qualified professional such as CEO enterprise, Industrialization manager, etc. The majority of these companies met quality stander, as 70% are ISO 9001 certified. It is shown in Table 2, respondent companies consisted of various type of industry with 27.3% from electronics industry, 24.2% from automotive from industry, 12.1% from health

Table 2: Profile the respondents

Type of industry	Frequency	%
Electronic Industry	10	27.3
Automotive Industry	7	24.2
Health Industry	4	12.1
Service	6	18.2
Transport	2	6.1
Other	4	12.1
Age of the companies		
Less than 5 years	1	3.0
Between 5 and 10 Years	4	12.1
Between 10 and 15 years	3	9.1
More than 15 Years	25	75.8
Method implemented		
Lean Manufacturing	20	60.6
Lean and six sigma	9	27.3
Don't chosen either lean or six sigma but practice various lean manufacturing and six sigma practices	4	12.1
Number of years		
Less than 3 years	16	48.5
Between 3 and 6 years	9	27.3
Between 6 and 9 years	2	6.1
9 years and more	6	18.2
Number of employees		
From 0 to 9 employees	2	6.1
From 10 to 49 employees	4	12.1
From 50 to 249 employees	6	18.2
From 250 employees and more	21	63.6

Table 3: Lean and six sigma tools

Tools	%	Tools	%
Brainstorming	100	Poka-yoke	81.8
Standardized work	97	VSM	81.8
Visual control	97	Gemba	78.8
PDCA	97	Kanban	78.8
Cause and effect diagram	97	SMED	72.7
5S	93.9	Control chart	72.7
Pareto chart	93.9	Takt time	69.7
Flow chart	93.9	Design of Experiment	63.6
Check sheet	90.9	DPMO	60.6
TPM	84.8	Once piece flow	57.6
VOC	84.8	DMAIC	57.6
FMEA	84.8	Cellular layout	48.5
Kaizen team	81.8	Regression analysis	39.4
Poka-yoke	81.8		

industry, 6.1% from Transportation, 18.2% from service and 12.1% of respondents were from other industries. Majority of the age organizations 75.8% were more than fifteen years. Four organizations 12.1% of the responding organizations were between five years to ten years. Three organizations 9.1% were between ten years to fifteen years and an organization 3% was less than 5 years. The methodologies implemented by companies were that twenty companies 60.6% had implemented lean manufacturing even though most of these companies had implemented six sigma practices such as Design of Experiments (DOE), Defect Per Million Opportunities (DPMO) and DMAIC. Nine companies 27.3% had implemented lean manufacturing and six sigma and four companies 12.1% had indeed implementing many of the lean manufacturing and six sigma practices, although these organizations did not refer to them as lean manufacturing or six sigma. The number of years of experience that the majority of French organizations 48.5% have implemented the lean manufacturing or/and six sigma methods was less than three years; 27.3% from three to six years, 6.1%from six to nine years and 18.2% from nine years and more. Twenty-one companies 63.3% had more than two hundred and fifty employees; followed by 6 companies 18.2% with employees ranging from 50 to 249 employees, 4 companies 12.1% with employees ranging from 10 to 49 employees and 2 companies 6.1% had less than 10 employees. The respondent companies were asked to demonstrate the techniques, which they had implemented and not implemented from amongst the 26 available practices for the purpose of identifying whether the companies had actually implemented lean and six sigma within their companies. It is evident from Table 3, that majority of the companies' implemented lean manufacturing and six sigma practices. Most of these companies highly practiced Brainstorming, Standardized work, visual control and PDCA, causes and effect diagram and 5S, indicating that the majority of these companies implemented the basic tools of lean manufacturing and six sigma. Majority of these companies implemented these tools and techniques in order to make continuous improvements in the product as well as services to ensure that there exists customer satisfaction and improve the bottom line. On the other hand, few companies recognized the importance of statistical tools such as practices of Design Of Experiment (DOE), Defect Per Million Opportunities (DPMO), DMAIC and regression analysis. This showed lack of knowledge or awareness of statistical tools and challenges facing implementation of six sigma tools within the French industry.

Compare success factors lean and six sigma: Comparison of fifteen success factors between lean manufacturing and six sigma has been made. Since the data that were used in this study were ordinal, Wilcoxon signed rank test was used in the comparison of identical success factors across lean manufacturing and six sigma. This, being a non-parametric test, has been designed to test repeated measures such as the comparison between lean manufacturing and six sigma across the identical success factors. The distinguish analysis was conducted to determine whether the two grouping variables (group 1 = Lean manufacturing, group 2 = Six sigma) were significantly different from each other or not with respect to their level of importance for the identical success factors.

The key success factors of lean manufacturing and six sigma are presented in Table 4, which descriptive statistics has been used in describing the average for each success factor. It shows that there is a difference in priority with respect to level of important for each method such as second important success factor for six sigma with mean value 3.55 is for project prioritization and selection as well as reviews tracking. This result is supported by Antony (2004), found that project prioritization and selection is the first critical success factors of implementing six sigma. On the other hand, communication was the second important factor of implementing lean manufacturing with mean value 4.39. However, linking either lean or six sigma to supplier were the lowest important factors (the same level of ranking) of implementing lean with mean score 2.58 and six sigma with mean score 2.33. This indicates French industries are not interested in transferring the method to supplier. The aim of lean manufacturing and six sigma are not only to minimize the variation but also to reduce lead-time within the organization, although longer lead time causes organizations to increase inventory and to decrease productivity. Therefore, it is advisable to encourage supplier to adopt lean six sigma since both are important in enhancing the improvement of quality and productivity (George, 2002).

In Table 5, some factors were found to be statistically insignificant whereas others were found to be statistically significant in comparison between lean

Table 4: A comparable ranking the success factors between of implementing lean and six sigma

Rank	Success factors Lean	Mean	Success factors Six sigma	Mean
1	Top management commitment and support	4.70	Top management commitment and support	4.33
2	Communication	4.39	Project prioritization and selection, reviews and tracking	3.55
3	Involvement of employees	4.24	Involvement of employees	3.55
4	Linking lean Method to the business strategy	3.97	Linking six sigma Method to the business strategy	3.52
5	Education and training	3.97	Communication	3.52
6	Understanding the tools and techniques within lean method to the employees that perform job in shop floor	3.97	Skills and expertise	3.45
7	Cultural change	3.97	Education and training	3.45
8	Monitoring and evaluation of performance	3.82	Cultural change	3.30
9	Leadership	3.67	Understanding the tools and techniques within six sigma to the employees that perform job in shop floor	3.06
10	Skills and expertise	3.64	Linking six sigma to customers	3.06
11	Understanding the tools and techniques within lean to the employees that perform job in an office	3.61	Project Management skills	3.06
12	Project Management skills	3.36	Understanding the tools and techniques within six sigma to the employees that perform job in an office	2.91
13	Linking lean to customers	3.30	Linking Six Sigma to human resources	2.73
14	Linking lean to human resources	3.15	Consultant participation	2.64
15	Kaizen team	3.06	Belt system	2.61
16	Consultant participation	2.85	Reward system	2.39
17	Linking lean method to suppliers	2.58	Linking six sigma method to suppliers	2.33
18	Reward system	2.58		

Table 5: Wilcoxon signed ranks test for comparison the key success factors of implementing lean vs. six sigma

Success factors	Z	p-value
Top management commitment and support	-1.414	0.157
Involvement of employees	-2.946	0.003**
Linking the method to suppliers	-1.356	0.175
Education and training	-2.173	0.030
Communication	-3.593	0.000**
Linking method to the business strategy	-1.982	0.048*
Consultant participation	-1.144	0.235
Understanding the tools and techniques within method to the employees that perform job in shop floor	-3.170	0.002**
Understanding the tools and techniques within to the employees that perform job in an office	-2.674	0.007**
Cultural change	-2.664	0.008**
Skills and expertise	-0.794	0.427
Reward system	-1.191	0.234
Linking the method to customers	-1.052	0.293
Linking the method to human resources	-2.336	0.019*
Project Management skills	-1.482	0.138

Note: Significant level of important factors on Wilcoxon signed ranks test at the 0.05*, 0.01** level of significance

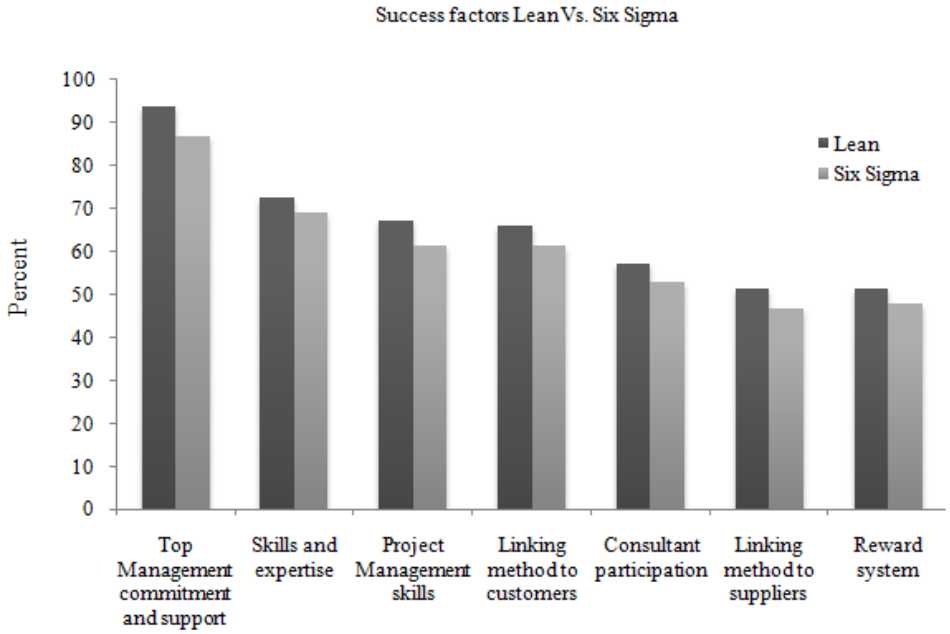

Fig. 1: Comparison lean manufacturing vs.six sigma across key success factors that statistically insignificant

manufacturing and six sigma methodologies across the identical success factors. The result shows no significance difference between lean and six sigma methodologies across some of the identical success factors ($p>0.05$ and 0.01). These factors are top management commitment and support, linking method to supplier, skill and expertise, linking method to customer, consultant participation and reward system and project management skills. These infer that these factors had the same level of important of implementing either lean manufacturing or six sigma. First critical factor is top management commitment and support which had equal level of importance to success, whether of implementing lean manufacturing or six sigma and ranking the first critical factors of implementing lean manufacturing with mean score value 4.70 and six sigma with mean score 4.33. Skills and expertise ranking is the tenth important factor of implementing lean manufacturing with mean score 3.64 and sixth important factor of implementing six sigma with mean score 3.45. However, the main conclusion from Fig. 1 and Wilcoxon test that lean manufacturing and six sigma have similar level of important to success of either lean manufacturing or six sigma implementation whereas each methods has different priority factors within French industry.

On the other hand, this study found statistically significant differences between lean manufacturing and six sigma across some common success factors by conducting Wilcoxon signed rank test, since the p-value was lower than significance level 0.05. First factor that had significant different between lean manufacturing and six sigma was the involvement of employees. Involvement of employees was perceived to have high difference of mean score between lean manufacturing with mean score 4.24 and six sigma with mean score 3.55. The average mean score for lean manufacturing were significantly higher than six sigma. The alternative hypothesis (statically significant difference between lean and six sigma in terms involvement of employees) was accepted. Therefore, this implied that lean manufacturing need a more involvement of the employees than six-sigma method. Various investigators had supported this result by viewpoint of academics and practitioner. According to Antony (2011), implementation of six sigma does not include people in improvement tasks, as implementation of lean requires people engaged at the grass root levels with the help of continuous and creative activities such as establishment of a Kaizen Team. Furthermore, people require specific set of skills and competencies prior to handling projects associated with the implementation of six sigma in the organizational framework. Although, Feng and Manuel (2008), indicated that implementation of six sigma can be performed without the involvement of either Master Black belt or green belt. In the other hand, Kumar and Antony (2009), highlighted that one of the reasons why organizations failed to implement lean in the first time is caused by involvement of employees in case of SME. However, based on this study result and analysis of these finding from literature review, it becomes clear that the degree of involvement of the employees within lean manufacturing is more critical than six sigma method to the success of the implementation. Consequently, it suggested that companies willing to implement lean need the capacity to create extensive involvement between the employees within their organization since aid to successful implementation and so on for other factors were statically significant.

Communication was the second factor that was significantly difference between lean manufacturing and six sigma. Communication was the highest priority success factor to implementing lean manufacturing with mean value 4.39 compared to six-sigma method with mean value 3.52. This may be explained that lean method exclude organization infrastructure that can have less communication whereas six sigma is a method where employees can have an effective communicate since it requires the building of organization infrastructure (MBB, BB, GB). It is effective in making the employees to communicate in common language between them. According to George (2003), the reason why lean needs six sigma is the exclusion of organizational infrastructure. Intensive communication is necessary among employees in an organization for lean manufacturing to be implemented successfully (Manotas Duque and Rivera Cadavid, 2007; Pingyu and Yu Yu, 2010). Scherrer-Rathje *et al*. (2009), also confirmed this notion by reporting that lack of communication in the organization results in unsuccessful implementation of lean. Although effective communication as well ensures successful implementation of six sigma within the organizational framework (Coronado and Antony, 2002; Ho *et al*., 2008). Based on the results, it could require more extensive communication within lean method than six sigma for having success in the implementation of lean manufacture. Therefore, it may simplify that degree of communication within lean manufacturing have high priority and more imperative than six sigma method.

Lean originated from the automobile industry through cultural of Japanese people with the aim of improving process flow through elimination of wastes. On the other hand, six sigma was initiated from electronics industry through cultural atmosphere developed by Americans and it tries to encourage effectiveness through the enhancement of quality and accuracy through the reduction of variations. Both the concepts of lean manufacturing and six sigma were developed by different nations having different cultural backgrounds (Chen, 2008; Laureani and Antony, 2010). It was revealed in the literature review that

organizational culture as well as change in management is the highlighted critical factors for implementation of lean manufacturing and six sigma in organizations. Although lean manufacturing tools are relatively more analytical, tools which are employed in six sigma are more statistical (Andersson *et al*., 2006) Hence, there is a need to consider that lean requires a substantial change in behavior of employees such that they establish good habits in their work environment. Because of this reason, some companies hold the opinion that lean method can only succeed within Japanese culture, but this is misunderstanding of lean philosophy (Arnheiter and Maleyeff, 2005). On the other hand, six sigma is more concerned with understanding statistical requirement of changing employees who fully understand the concept of how to solve problem such as executing DMAIC framework, defect per million opportunities and design of experiment and statistical thinking (Kwaka and Anbari, 2006). However, Culture change is success factor of implementinglean manufacturing and six sigma, but significant differences ($p<0.01$) were found between lean manufacturing and six sigma. The average mean scores for lean were significantly higher than six sigma. This indicates that lean manufacturing need more extension of changing culture than six sigma method. An example of author's opinion as to why implementation of lean need changing culture and is more essential than six sigma methodologies, operating 5S system considers unique of lean tools and technique that help to reduce waste. It is easy to understand the concept of 5S but it may be difficult to perform everyday by the employees in their work, as it requires changing behavior of people. 5S system demand employees to practice 5S as routine with their work environment (Gunasekaran and Lyu, 1997). Puvanasvaran (2012), outlined very few companies succeed in implementing lean manufacturing practices, one of the causes behind ineffective execution of lean manufacturing is the distinctive behavior displayed by employees in the workplace. Furthermore, behavioral change is considered as the key of having a sustainable and successful development and implementation of lean manufacturing (Emiliani, 1998). In addition, Wilson

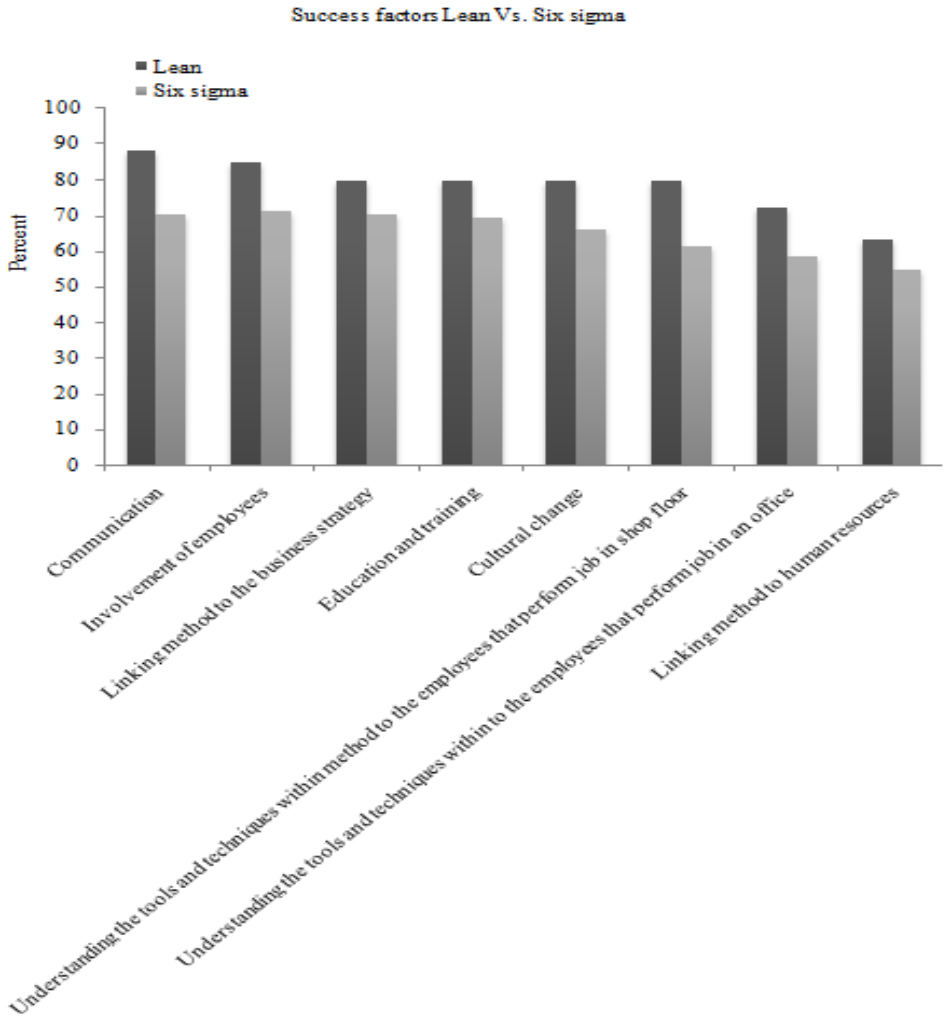

Fig. 2: Comparison lean manufacturing vs. six sigma across key success factors that statistically significant

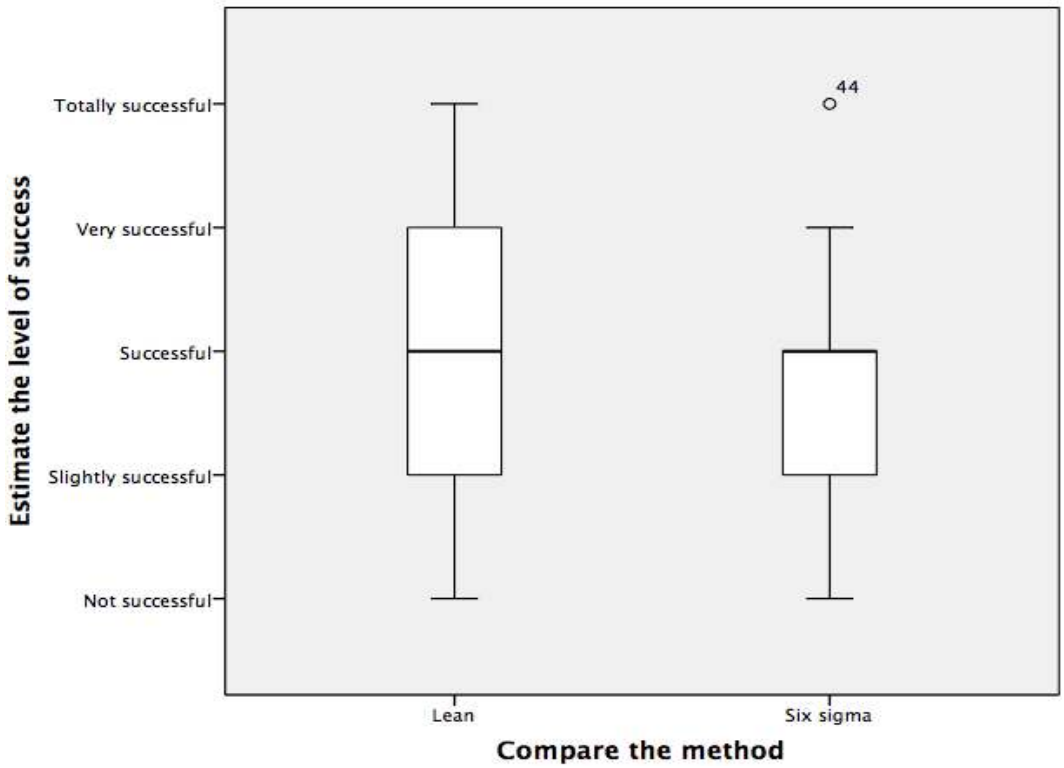

Fig. 3: Box plot showing the distribution of success level between lean manufacturing vs. six sigma

(2010), specified that it must be ensured that evaluations must be based upon behavior of people and not just through word-of-mouth. Hence, there is need to consider that lean requires a substantial change in behavior of employees such that they establish good habits in their work environment. However, (Nave, 2002) suggested that selecting appropriate method depended on organization culture and in this regard, changing culture of an organization is imperative for the success in the implementation. Consequently, it is important for companies to realize which of either path has the capability to change of their organization culture to leanor six sigma or lean and six sigma. Thus may helping to identify and pick appropriate method dependent on the capacity of the company of changing culture. This is can be supportive in the selection of appropriate method that fit with their organization.

The rest of the factors were significantly different ($p<0.01$ and 0.05). They included understanding the tools and techniques within method, education and training, linking the method to the business strategy and linking the method to human resources between lean manufacturing and six sigma. This was a remarkable result, although it was hard to clarify the reasons since these factors are important for the implementation of lean manufacturing and six sigma. The main conclusion from Fig. 2 and the Wilcoxon signed ranks test that lean and six sigma have seven significantly different factors with respect to the level of importance to successful implementation between lean manufacturing and six sigma with French industry.

Others success factor that has been mentioned by the respondents from the open end of the questionnaire to successful implementation of six sigma that six sigma is a method required to use on specific cases with a small number of people (tools complex), strong knowledge of statistics and culture of statistical evidence, while to succeed in the implementation of lean manufacturing is to implement GEMBA (Helpful to be able to see and understand the problems) and finance.

The respondents were finally asked to rate the degree of success of implementation of each of lean manufacturing and six sigma using a five point scale, choosing from 1 = “not successful” to 5 = “totally successfully”. The level of success was summarized in the Box Plot shown in Fig. 3. The companies whose success levels were anonymous were not included in the analysis due to the fact that they had not implemented either lean manufacturing or six sigma (Did not participate in the estimation of the success implementation) with their organization. Therefore, the response of not implemented was excluded with their companies into missing value. Majority of the companies (N = 29) did participate in the level of success for the implementation of the lean manufacturing as compared to few companies (N = 9) that did participate in the level of success for the implementation of six sigma.

Further analysis was made for the 21 out of the 29 companies that implemented lean manufacturing successfully by excluding companies that were not

Table 6: Success factors of implementing lean manufacturing

Success factors of implementing lean	Mean
Top Management commitment and support	4.86
Communication	4.43
Involvement of employees	4.24
Cultural change	4.14
Linking lean Method to the business strategy	4.05
Education and training	4.05
Monitoring and evaluation of performance	4.00
	N = 21

Table 7: Success factors of implementing six sigma

Success factors six sigma	Mean
Top Management commitment and support	5.00
Communication	4.20
Education and training	4.20
Skills and expertise	4.00
	N =5

successful and those slightly successful. This helped in recognizing the most critical success factors for the implementation of lean manufacturing within their companies. A mean value less than 4 was also excluded due to the fact that it was not considered critical for the successful implementation of lean manufacturing. Table 6 shows top management commitment, commination, involvement of employees, culture change, linking lean method to the business strategy, education and training, monitoring and evaluation of performance are the most critical factors of implementing lean manufacturing.

A similar criterion was followed for six sigma, although the sample size was significantly smaller having only 9 companies that participated in the success level for six sigma. We made the analysis to compare between lean manufacturing and six sigma to the companies that have successful implementation. 5 out of 9 companies that successfully implemented six sigma were included and the other four companies were excluded since they were either not successful or were slightly successful. This helped in recognizing the most critical factors and the manner in which these companies have the most success factors of implementing six sigma. In Table 7, top management commitment, commination, education and training, skills and expertise and communication are the most critical success factors for six sigma.

Some observation from the Table 6 and 7, it was found out that the top management support is the one that was critical to success of implementing either lean manufacturing or six sigma. It was also found out that culture change and involvement of the employees emphasized what was previously illustrated that these factors are critical to success of implementing lean manufacturing. On the other hand, skill and expertise is critical factors to success the implementation of six sigma. This study only used a small sample for six sigma, it is recommended that a large sample should be used for six sigma in future research in order to verify the success factors of implementing six sigma for the companies that have successfully implemented six sigma.

Key success factors are required and expected to enhance the success of implementing either lean manufacturing or six sigma. Consequently, this has made it necessary to test the success factors so as to identify the similarities and difference between lean manufacturing and six sigma to expose the level of importance concerning the key success factors for each method. Therefore, the results found in this study can be useful in the comparison between lean manufacturing and six sigma for several reasons:

First, the results indicated that there were significant differences between implementing lean manufacturing and six sigma across success factors as well as difference in priority factors for each method. So Companies which are willing to apply lean manufacturing or six sigma or both methodologies at the same time can be aware and more focused on understanding the factors that make successful implementation of the methodologies.

Secondly, as reported in the literature, an organization can achieve a significantly rapid improvement in both efficiency and production when there is simultaneous application of both lean manufacturing and six sigma, whereas implementation of either of lean or six sigma before the other bring about lack of improvement in terms of inventory, added value, etc, the combined lean and six sigma have the effect of improving process speed, inventory, reduced recycled time, added value, among other improvements (George, 2002; Breyfogle III, 2003; Arnheiter and Maleyeff, 2005; Sorqvist, 2009; GamalAboelmaged, 2010; Pepper and Spedding, 2010). There are many advantages of implementing both lean manufacturing and six sigma that are acquired by implementation of both methods simultaneously, but the organization requires maturity and clear strategy (Bertels, 2003). However, the simultaneous implementation of both methods lean and six sigma may not be achievable by every organizations, especially SME, due to lack of resources such as time, finance, expert. Various researchers have studied organizations, which have implemented lean and six sigma at different times, by beginning with one method either lean (Kumar and Antony, 2009), or six sigma (Snee, 2010) followed by the other with success. One of the important factors that researchers often fail to take into consideration when recommending simultaneous implementation of lean manufacturing and six sigma is the fact that some organizations lack sufficient resources for implementing both philosophies simultaneously. This has prompted most companies to try to identify the best method between lean or six sigma or theory constrain that is the most applicable in their organization and the implementation of one of the methods may yield similar result due to the fact that each method can bring valuable idea, concept and technique to the organization (Nave, 2002). Furthermore, the experts were asked to answer questions by selecting one statement that SME should follow when implementing lean manufacturing

Table 8: Status integration of lean and six sigma and their recommended to begin implemented in case SME

Companies implemented lean and Six Sigma in the same time	Lean First then six sigma	Six sigma First then lean	Lean and six sigma Simultaneously	Doesn't know	Doesn't matter
Yes (18.2%)	50.0%	33.3%	16.7%	0.0%	0.0%
No (81.8%)	40.7%	0.0%	11.1%	33.3%	14.8%

and six sigma. The results displayed in Table 8 show that the majority of sampled companies (81.8%) havenot implemented both lean manufacturing and six sigma simultaneously. Furthermore, the results demonstrated that a few respondents preferred to begin the implementation of lean manufacturing and six sigma in SME simultaneously. Additionally, the results show, surprisingly, that some companies that implemented lean and six sigma simultaneously and had recommended the implementation of one of the methods before the other. This can be explained by the fact that SME have fewer resources and do not have the capacity to implement lean and six sigma simultaneously. Therefore, since it has been proven that the implementation of either of lean manufacturing and six sigma at different time can also be successful, it is very significant to consider the factors that influence successful implementation of each method. According to Kumar *et al*. (2006), clear guidance in the framework is lacking during the project's initial stages on which of the methods is suitable between either lean or six sigma or combination of lean and six sigma. Thus, deciding on whether an organization is to begin with either lean or six sigma depends on factors such as the organization's capability to implement either of the two methods, once the organization gets positive impact and growth, it can integrate it with other method since the integration of lean manufacturing and six sigma work more effective to improve quality, improve productivity and satisfy customer.

Lastly, as it has been found that there were significant difference between lean manufacturing and six sigma methodologies with respect to level of importance, it is valuable to make organization aware of the critical factors as well as the priority factors for each method. Consequently, a company may have clear guidance to determine appropriate method (whether to implement lean manufacturing or six sigma or both methods) in order to make the necessary plans for the implementation by taking into consideration the success factors of each method.

CONCLUSION AND RECOMMENDATIONS

This study raises assessment specifically on comparing the key success factors between lean manufacturing and six sigma. Some companies which are confused of selecting improvement tools such as lean manufacturing, six sigma, or theory of constrain that is precise to the environment of their business (Chakravorty, 2009). It seems that some companies have challenge of selecting the appropriate method. Therefore, critical factors that lead to success can support the organization to recognize the method by realizing the key success factors of each method. This might guide the companies that are willing to implement either lean manufacturing or six sigma or lean manufacturing and six sigma simultaneously based on their need. It is necessary to take into consideration the key success factors of each method so as to decide whether companies have the capabilities to implement the success factors or not, since it is helpful in the success of implementation. It can be interpreted that the companies in France sampled in this study are facing difficulties in integrating lean and six sigma simultaneously due to several reasons such as lack of knowledge, company culture, finance and lack of top management commitment. Further research should be conducted on the feasibility of integrating lean and six sigma with a modified or simplified version of two methodologies. This is necessary since literature review indicates that implementing either lean or six sigma alone is insufficient to meet the demands of a competitive market. Research is also needed to further validate the factors such as linking the method to the business strategy and linking the method to human resources, among other factors that show significant difference in level of importance between implementing lean manufacturing and six sigma due to the fact that these factors are important from previous studies for the implementation of either lean manufacturing or six sigma. Therefore, these factors should be broken down into sub factors so as to include more aspects in the future research.

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