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Research Paper

A STUDY ON LEAN MANUFACTURING TOOLS AND TECHNIQUES IMPLEMENTATION IN THE ANDHRAPRADESH SILK PRODUCTION INDUSTRY

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The purpose of this study is to investigate the adoption of lean manufacturing tools and techniques in the silk production Industry, A questionnaire survey was used to explore 14 key areas of lean manufacturing namely, scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, and tools and techniques. The respondents were asked to rate the extent of implementation for each of these areas. The average mean score for each area was calculated and some statistical analyses were then performed. In addition, the survey also examined various issues associated with lean manufacturing such as its understanding among the respondent companies, its benefits and obstacles, the tools and techniques used, etc. The survey results show that many companies in the Silk Production industry are committed to implement lean manufacturing. Generally, most of them are "moderate-to-extensive" implementers. All the 14 key areas investigated serve as a useful guide for organizations when they are adopting lean manufacturing. In essence, this is perhaps the first study that investigates the actual implementation of lean manufacturing in the Silk production industry.

Keywords: Lean manufacturing tools and techniques, Silk production industry, Andhra Pradesh

INTRODUCTION

Manufacturers in the silk production industry have always faced heightened challenges such as rising customers' expectation, fluctuating demand, and competition in markets. There is no doubt that these manufacturers are always embracing changes and improvements in their key activities or processes to cope with the challenges. One way to stay competitive in this globalized market is to become more efficient. Lean manufacturing has been receiving a lot of attentions in the industry. The

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effects claimed after implementing it are enormous. Lean manufacturing uses less of everything compared to mass production-half the human effort in the factory, half the manufacturing space, half the investment in tools, and half the engineering hours to develop a new product (Womack *et al.*, 1990). It has now become a production method for many manufacturers to pursue.

Little studies regarding lean manufacturing have been done in Andhra pradesh. A survey needs to be carried out in order to gauge how organizations in this practice it. This research was initiated with a focus to examine the adoption of lean manufacturing tools and techniques in the silk production industry. Various issues such as its understanding among the respondent companies, its benefits and obstacles, the tools and techniques used etc, were investigated. In addition, the degree of implementation of 14 key practice areas of lean manufacturing was assessed.

This paper begins with a general overview of lean manufacturing tools and techniques and the key areas that characterize its adoption. This is followed by an outline of the methodology employed for conducting the survey. Findings of the survey together with the results of some statistical analyses that were applied are presented in the next section. Finally the paper ends with conclusions.

LITERATURE REVIEW

Principles of lean thinking have been broadly accepted by many manufacturing operations and have been applied successfully across many disciplines (Poppendieck, 2002). While many researchers and practitioners have studied and commented on lean manufacturing, it is very difficult to find a concise definition which everyone agrees. Different authors define it distinctively. Lean manufacturing is most frequently associated with the elimination of seven important wastes to ameliorate the effects of variability in supply, processing time or demand (Shah and Ward, 2007). Liker and Wu (2000) defined it as a philosophy of manufacturing that focuses on delivering the highest quality product on time and at the lowest cost. Worley (2004) defined it as the systematic removal of waste by all members of the organization from all areas of the value stream. Briefly, it is called lean as it uses less, or the minimum, of everything required to produce a product or perform a service (Hayes and Pisano, 1994). In a nutshell, lean manufacturing can be best defined as an approach to deliver the upmost value to the customer by eliminating waste through process and human design elements.

Lean manufacturing has become an integrated system composed of highly inter-related elements and a wide variety of management practices, including Just-in-Time (JIT), quality systems, work teams, cellular manufacturing, etc. (Shah and Ward, 2003). The purpose of implementing it is to increase productivity, reduce lead time and cost, and improve quality (Karlsson and Åhlström, 1996; and Sánchez and Pérez, 2001).

Lean manufacturing requires that not only should technical questions be fully understood, but existing relationships between manufacturing and the other areas of the firm should also be examined in depth, as should other factors external to the firm (Womack and Jones, 1994). As an integrative concept, the adoption of lean manufacturing can be characterized by a collective set of key areas or factors. These key areas encompass a broad array of practices which are believed to be critical for its implementation. They are, scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, and tools and techniques (Wong *et al.*, 2009). These 14 areas are the subjects of investigation in this study and each of them will be reviewed and described now.

Scheduling has been widely discussed in lean manufacturing (Sohal and Egglestone, 1994; Harrison and Storey, 1996; and Karlsson and Åhlström, 1996). Effective schedules improve the ability to meet customer orders, drive down inventories by allowing smaller lot sizes, and reduce work in processes (Heizer and Render, 2006). Appropriate scheduling methods are able to optimize the use of resources. Pull methods such as Kanban, and lot size reduction are commonly used to reduce storage and inventories and to avoid overproduction. Pull means to do nothing until it is required by the downstream process (Poppendieck, 2002). Minimizing lot sizes enables a smoother production flow and maximizes productivity by eliminating production line imbalances.

Companies store inventories to enable continuous deliveries and overcome problems such as demand variabilities, unreliable deliveries from suppliers, and breakdowns in production processes. However, there is a need to maintain inventories at the minimum level because excess inventories would require more valuable spaces and result in higher carrying costs. Moreover, they accumulate the risk of “products becoming obsolete”. Excess inventories are seen as “evils” because they hide problems such as defects, production imbalances, late deliveries from suppliers, equipment downtime and long setup time (Liker, 2004).

Material handling is also crucial in lean manufacturing because the cost attributed to material handling is estimated between 15% and 70% of the total manufacturing operation expenses (Tompkins *et al.*, 1996). Karlsson and Åhlström (1996) and Sánchez and Pérez (2001) stated that transporting parts not only does not add value to a product, it increases manufacturing lead time. Hence, it is a major waste that needs to be eliminated. A steady material flow which moves frequently in small batches will allow a faster replenishment of materials. This will then shorten lead time and increase productivity.

The level of equipment support should be given attention in lean manufacturing (Mortimer, 2006) because some manufacturing processes rely heavily on their equipment to produce products. Unexpected machine downtime would result in line stoppage and decrease productivity. Therefore, equipment is a vital area in which maintenance and reduction of setup time play an important role to avoid process disturbance (Taj, 2005; and Shah and Ward, 2007). Lean manufacturing requires machines which are reliable and efficient. Inventories can be reduced when machine downtime is minimized.

Work processes across the value stream should also be emphasized in lean manufacturing. Processes should be performed with a minimum of non value added activities in order to reduce waiting time, queuing time, moving time, and other delays (Pattanaik and Sharma, 2009). Besides this, standardization of work processes is needed to facilitate efficient, safe work methods and eliminate wastes, while maintaining quality (Kasul and Motwani, 1997). It ensures a consistent performance and creates a foundation for continuous improvement.

Nowadays, a product with high quality is a prerequisite for any manufacturer. Quality is a major focus in lean manufacturing (Forza, 1996; Shah and Ward, 2003; and Taj, 2005) because poor quality management would result in many wastes such as scraps and rejects. Appropriate quality management helps to control a manufacturing process, and this reduces "safety" buffers and exposes quality issues (Nakamura *et al.*, 1998). Reduction of "safety" buffers will eventually lead to reduction of inventories.

Employees who are motivated and empowered are essential since people are the key element in lean manufacturing. Japanese regard people as assets (Sharp *et al.*, 1999) because they are the ones who are going to solve problems and improve processes in production. The phrase "No one knows the job better than those who do it" indicates that the person who is experienced in his/her job is most likely to have a better understanding on it. Task rotation creates cross-trained and multi-tasked employees, and this enables them to respond faster to changes in products and processes. In addition, work teams are critical throughout the implementation of lean manufacturing (Åhlström, 1998). It is said that work teams are the heart of a lean manufacturing company (Womack *et al.*, 1990).

Another key area of lean manufacturing is layout which determines the arrangement of facilities in a factory. A poor layout may have several deteriorating effects such as high material handling costs, excessive work-in-process inventories, and low or unbalanced equipment utilization (Heragu, 1997). Layouts that cause inventory accumulation and interrupt process flow should be eliminated. On the other hand, lean manufacturing needs flexible layouts that reduce movements of both materials and people, minimize material handling losses, and avoid inventories between stations.

Lean manufacturing is particularly vulnerable not only to internal sources of variability, but also to external resources (Davis, 1993). Suppliers have been reported as a critical factor for the success of lean manufacturing (Keller *et al.*, 1991) and they have been given much attention by various researchers (Panizzolo, 1998; Lewis, 2000; Sánchez and Pérez, 2001; and Wu, 2003). Particularly, it is important to encourage suppliers to develop JIT production capabilities as well as JIT delivery in order to enhance long-term competitiveness (Helper, 1991). A mutual goal between manufacturers and suppliers to reduce waste and cut down cost is crucial to drive lean manufacturing to success.

Relationship with customers is also crucial in lean manufacturing (Doolen and Hacker, 2005; and Shah and Ward, 2007). Customers decide what to buy, and when and how they are going to purchase a product. Since value is determined by the customers, it is essential to develop a good relationship with them. Setting up good relationships with customers will enable an organization to understand and meet their needs and predict their demands accurately, as it is important to attain a perfect match between market demands and production flows (Panizzolo, 1998).

Safety and ergonomics are incorporated as an area in lean manufacturing. Safety should be emphasized since it is the foundation of all activities. Ergonomics is also important because it helps humans to improve productivity, reduce injuries and fatigues (Walder *et al.*, 2007). By using ergonomic features, unnecessary motions (one of the major wastes) are decreased. This helps to reduce mistakes caused by human errors, thus enhancing the quality of products.

Product design is also important because the choices of product structures and materials would affect the production methods and costs. Karlsson and Åhlström (1996) found that concurrent engineering techniques play a vital role in a "lean" product development process. Moreover, continuous design improvements had enabled Toyota to improve its quality even further (Womack *et al.*, 1990).

Essentially, management and culture are considered as a key area in this study. It is critical for top management to understand and give ample support to sustain the lean concept. Communication between senior managers and employees is critical to ensure that the vision and mission of lean manufacturing is attainable. Evidence shows that management support plays a vital role in driving lean manufacturing implementation (Worley and Doolen, 2006). Recognition and rewards from top management will serve as a booster for participation and continuous improvement. In addition, culture is the main pillar when implementing lean manufacturing (Little and McKinna, 2005). A supportive culture that brings the employees to work, communicate and grow together is essential to make the initiative successful.

Finally, tools and techniques are indispensable in implementing lean manufacturing. Many researchers such as Sohal and Egglestone (1994), Kasul and Motwani (1997), Bhasin and Burcher (2006) and Abdulmalek and Rajgopal (2007) have highlighted some critical lean manufacturing tools in their studies. Lean tools that are systematically applied or implemented can help to define, analyze and attack sources of waste in specific ways. There are many excellent tools that are useful in different circumstances. Using tools such as value stream mapping, jidoka, 5S, kanban etc, will assist organizations to go along with lean manufacturing transformation. Lean tools are urged to be used in an integrated way (Cua *et al.*, 2001; White and Prybutok, 2001; and Liker, 2004) rather than applying them in isolation.

METHODOLOGY

This research aims to find out the adoption of lean manufacturing tools and techniques in the silk production industry in Andhra pradesh. To achieve this, data were collected via a questionnaire survey. This method seems to be the best data collection technique in exploratory studies since it enables a larger amount of data to be gathered in a short period of time.

The samples of organizations were obtained from the. They were randomly selected from those which have complete information and contact details. 350 manufacturers were identified and questionnaires were distributed to them using postal mail. The questionnaires were addressed to the General Managers or Managing Directors of the companies. They were considered to be the best addressees because they were likely to be the thought leaders in charge of lean manufacturing. However, it was up to the organization to assign the most appropriate person who has knowledge to answer the questionnaire. To increase the response rate, various techniques such as providing self- addressed stamped envelopes, making telephone calls, and sending follow-up letters were employed. Finally, a total of 52 responses were obtained. However, only 44 were valid for analysis, yielding a response rate of 12.6%. According to Jusoh *et al.* (2008), this feedback rate in postal survey was not unusual in Andhra pradesh as they obtained a response rate of 12.3%. Likewise, a response rate of 11.5% was obtained by Ahmed and Hassan (2003) in their study in Andhra pradesh. Therefore, the response rate for this research was considered to be reasonable.

The questionnaire consists of two parts. The first section surveyed the organization's background such as the total number of employees and the products manufactured. Awareness, benefits and obstacles of implementing lean manufacturing were also studied in this part. The second section consists of 52 items or elements that investigate the implementation of lean manufacturing practices. The items were designed based on the review of prior literature and they were grouped into the 14 key areas discussed earlier. A five-point scale was used in this study to indicate the degree of implementation for each of the items. This five-point scale, 1 = no implementation, 2 = little implementation, 3 = some implementation, 4 = extensive implementation, and 5 = complete implementation, was adopted from Shah and Ward (2007). The average mean values would indicate the level of implementation for each key area. Most of the questions in this study were close ended types, thus helping the respondents to answer them in less time.

Reliability and validity tests were conducted to ensure that the questionnaire was reliable and valid. Reliability tests were performed for each key area and Cronbach's Alpha with a minimum value of 0.60 was acceptable in this study. This is because a value of 0.6 is satisfying for a relatively new measurement instrument (Sakakibara *et al.*, 1997) while 0.7 is sufficient (Nunnally, 1978). As can be seen in Table 1, one item in layout was deleted to achieve a satisfying Cronbach's Alpha. Apart from this, all the other key areas show a construct reliability that is above the minimum limit. Content validity was determined by experts and by referring to the literature. Pilot studies were conducted involving 6 academics and 2 practitioners in lean manufacturing. Based on their feedbacks, some alterations were made before the questionnaires were distributed.

To assess construct validity, principal components analysis was used. Items that did not load into a single factor were eliminated

Table 1: Reliability and Validity Test Results

Key Areas	Cronbach's Alpha	Items Deleted	Eigen Value	% Variance Explained	Items for Deletion	Items Loading Range	KMO Value
Scheduling	0.688	None	1.893	63.095	None	0.767-0.814	0.671
Inventory	0.869	None	2.892	72.303	None	0.818-0.890	0.754
Material Handling	0.842	None	2.289	76.296	None	0.853-0.897	0.719
Equipment Work	0.878	None	2.413	80.424	None	0.887-0.916	0.735
Processes Quality	0.856	None	3.228	64.566	None	0.687-0.867	0.797
Employees	0.819	None	2.681	67.021	None	0.685-0.916	0.732
Layout Suppliers	0.864	None	2.850	71.250	None	0.795-0.929	0.720
Customers	0.600	1	1.431	71.552	None	0.846	0.500
Safety and Ergonomics	0.702	None	1.892	63.063	1	0.621-0.906	0.540
Product Design	0.780	None	2.140	71.342	None	0.798-0.888	0.680
Management and	0.812	None	2.226	74.194	None	0.785-0.945	0.569
Culture	0.821	None	2.263	75.420	None	0.774-0.918	0.662
Tools and Techniques	0.947	None	4.143	82.860	None	0.864-0.931	0.883
	0.817	None	2.923	58.458	None	0.685-0.867	0.749

(or considered in another factor) and the analysis was re- performed. As shown in Table 1, the Eigen value of each factor exceeds the minimum threshold of 1.0 and the explained variance of each factor is greater than 50%. All factor loadings are greater than 0.5 which are acceptable. Additionally, the Kaiser–Meyer–Olkin (KMO) values for sampling adequacy are satisfying since all of them exceed the minimum score of 0.5. In short, it can be said that all the factors or key areas are reliable and valid, and thus can be used for further analyses.

RESULTS AND DISCUSSION

Table 2 shows the descriptive statistics for the respondent companies in terms of their sizes, types of industry and the number of years for which they have adopted lean manufacturing. It can be seen that only 31.82% were from Small and Medium Enterprises (SMEs) while the remainder was large organizations. The

Table 2: Profiles of the Respondent Companies

	No. of Companies	Percent
a) Size of the Companies		
Small and Medium Enterprises	14	31.82
Large Organizations	30	68.18
Total	**44**	**100**
b) Types of Product Manufactured		
Silk Industry	26	59.09
Home Silk Industry	18	40.91
Total	**44**	**100**
c) Number of Years Adopted Lean Manufacturing		
<5 years	23	52.27
5-10 years	8	18.18
>10 years	13	29.55
Total	**44**	**100**

classification of companies' size was based on the definition provided by the Andhra pradesh SME Development Council (2011). In this research, large companies are those that have more than 150 employees in total. Apparently, there are more large organizations than SMEs which have implemented lean manufacturing. This is consistent with the findings of Shah and Ward (2003) as they found that larger plants across a variety of industrial sectors were more likely to implement lean manufacturing practices.

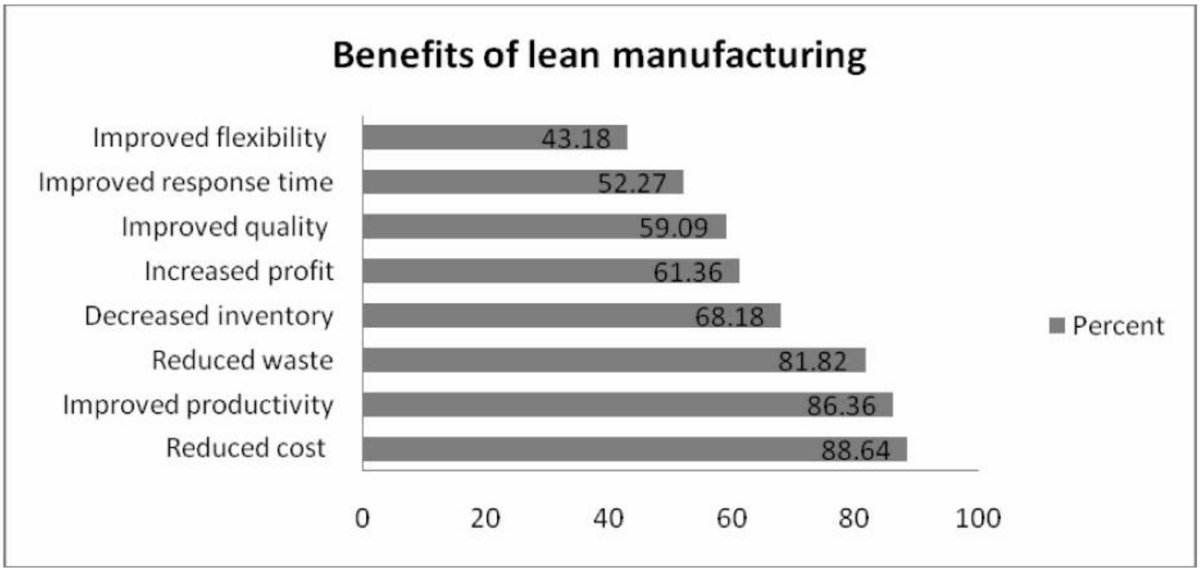
This survey also investigated the number of years for which the respondent companies have been involved in lean manufacturing to indicate their maturity in the field. It appears that more than half of the respondents have been involved in lean manufacturing for less than five years, 18.18% have adopted it for five to ten years, while 29.55% have implemented it for more than ten years.

In an attempt to discover the understanding of lean manufacturing among the respondents, they were asked to indicate what they thought it was associated with (eight choices were given). Waste reduction and continuous improvement were the highest ranked which scored 88.64% and 84.09% respectively. It is remarkable that most respondents identified lean manufacturing as an approach for waste reduction and continuous improvement since it is a concept that emphasizes on these two principles. The respondents seem to have a high understanding of lean manufacturing in which its basic is to use lesser resources for further improvement and growth. 54.55% of the respondents perceived it as tools and techniques to improve operations. Interestingly, only 36.36% associated it with the Toyota Production System which is the root of lean manufacturing. Figure 1 summarizes the respondents' answers regarding their understanding of lean manufacturing.

Figure 1: Understanding of Lean Manufacturing

The respondents were also asked to identify the benefits of lean manufacturing in their respective companies. It was clear that they gained various benefits after practicing lean manufacturing (as shown in Figure 2). The highest benefit is reduced cost, followed by improved productivity and reduced waste. More than 80% of the respondents have gained these benefits after embarking on lean manufacturing. However, only 43% were able to improve flexibility after implementing it. Based on the results, there is a clear relationship between lean manufacturing and productivity.

Figure 2: Benefits of Lean Manufacturing



In order to further verify whether the respondent companies had really embarked on lean manufacturing, they were asked to indicate which tools they had implemented from a list of 18 tools. As can be seen in Table 3, a majority of them were found to be implementing 5S (88.64%) and Kaizen (84.09%). This shows that in general, keeping the manufacturing plant in order and maintaining a good housekeeping seem to be the highest priority among the respondents. However, Group Technology (6.82%) was the least adopted in the silk production industry probably because it demands a large investment in equipment and facilities (White and Prybutok, 2001).

Table 3: Tools Applied in the Respondent Companies

Tools and Techniques	Overall %	Rank
5S	88.64%	1
Kaizen	84.09%	2
Standardized Work	70.45%	3
PDCA	70.45%	3
Poka-Yoke	63.64%	5
Kanban	61.36%	6
JIT	54.55%	7
TPM	54.55%	7
One Piece Flow	40.91%	9
TQM	40.91%	9
VSM	36.36%	11
Cellular Layout	34.09%	12

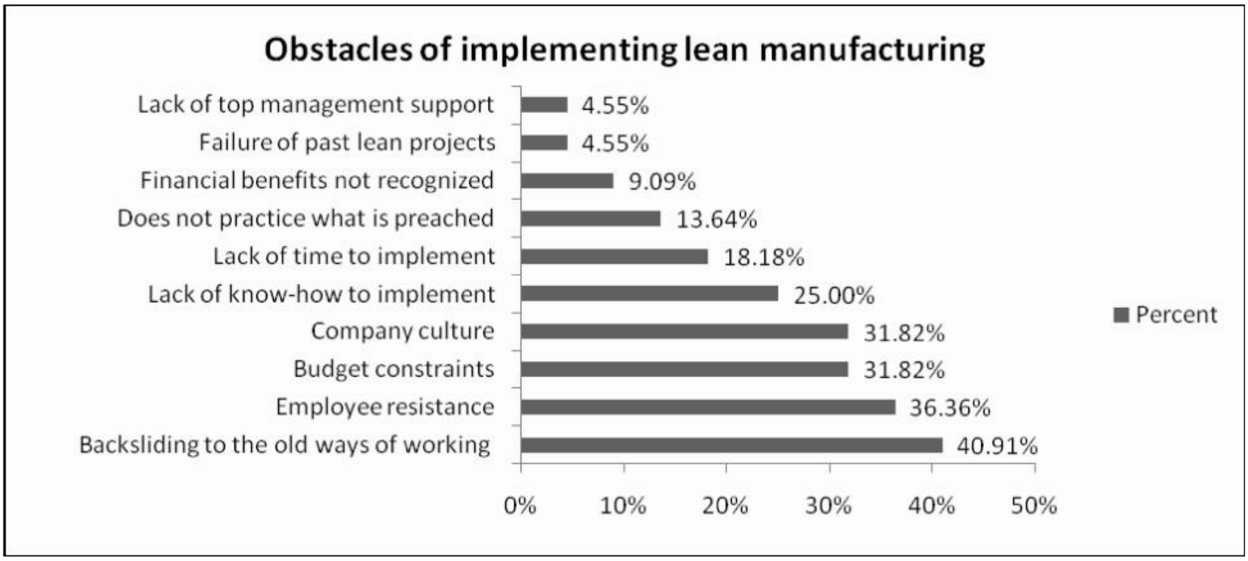
The tools implemented were also analyzed based on the number of years for which the respondent companies have implemented lean manufacturing (see Table 4). The five most adopted tools among the beginners in lean manufacturing (less than 5 years of implementation) were Standardized work, 5S, Kaizen, Kanban, and PDCA. This is understandable since most of these tools are simple techniques which require less time to be planned and implemented. While for the 5 -10 years implementers, most of them were implementing 5S, Poka-yoke, Kaizen, JIT, and Standardized work. Poka-yoke needs more time and funding support because some instruments or jigs and fixtures or even design changes are needed to implement mistake-proofing features. Likewise, JIT is a long term manufacturing philosophy that would require the whole organizational system to change. 5S, Kaizen, PDCA, TPM and JIT were the five most implemented tools in the companies that have practiced lean manufacturing for more than 10 years. As the companies become more advanced and knowledgeable in this field, lean manufacturing is practiced in a wider scope involving TPM to prevent the breakdowns of equipment or facilities. According to Herron and Braident (2007), lean tools should not be implemented in isolation; they were developed for a reason, which was to support an overall strategy. Bhasin and Burcher (2006) also suggested that it was better to embrace more lean tools rather than practicing one or two isolated ones. The analysis above shows that the respondent companies have been implementing various lean tools concurrently.

The obstacles of implementing lean manufacturing were also investigated. From Figure 3, backsliding to the old ways of working was the biggest problem, followed

Table 4: Tools Ranking Based on the Number of Years of Lean Manufacturing Implementation

< 5 Years of Implementation		5-10 Years of Implementation		> 10 Years of Implementation	
Tools	**%**	**Tools**	**%**	**Tools**	**%**
Standardized Work	82.60%	5S	100.00%	5S	100.00%
5S Kaizen	78.30%	Poka-Yoke	100.00%	Kaizen	92.30%
Kanban	78.30%	Kaizen	87.50%	PDCA	76.90%
PDCA	69.60%	JIT	87.50%	TPM	69.20%
Poka-Yoke	69.60%	Standardized Work	75.00%	JIT	53.80%
One Piece Flow	60.90%	Kanban	62.50%	TQM	53.80%
TPM	47.80%	PDCA	62.50%	Poka-Yoke Kanban	46.20%
JIT	47.80%	Andon	50.00%	Standardized Work	46.20%
Cellular Layout	43.50%	TPM	50.00%	Heijunka	46.20%
VSM	39.10%	Cellular Layout	37.50%	One Piece Flow	30.80%
Heijunka	39.10%	SMED	37.50%	VSM	30.80%
TQM	34.80%	One Piece Flow	37.50%	Cellular Layout	30.80%
	n = 23		n = 8		n = 13

Figure 3: Obstacles of Implementing Lean Manufacturing



by employee resistance. Therefore, the major roadblocks of implementing lean manufacturing in the respondent companies seem to be the "people" factor. The employees reverted to the old ways of working probably because lean manufacturing initiatives might have burdened them with additional work. Resistance from employees might be due to the "fear factor" that they would lose their jobs if they find out that their jobs do not add values, since lean manufacturing is about eliminating non value added activities. Therefore, it is crucial that top management gives ample support as well as job security to the workers to obtain their "buy-in". Lean manufacturing potential benefits should also be made known to all employees to ensure that they are supportive and have a common goal to achieve it.

The primary objective of this research was to explore the extent of lean manufacturing implementation in the silk industry in Andhra pradesh. The extent of implementation was determined by calculating the average mean score for each of the key practice areas mentioned earlier. A higher average mean value implies a higher degree of implementation. The results are shown in Table 5. The average mean scores were ranged from 3.174 to 4.250. When the key areas were arranged in order of magnitude, customers were shown to be the highest implemented area, with an average mean score of 4.250. The 2nd highest ranked was management and culture (average mean score = 4.114) and the lowest ranked was product design (average mean score = 3.174). The variability observed was almost similar for each of the key areas.

Customers have the highest degree of implementation, thus indicating that the respondent companies were giving the highest priority to their clients. Focusing on customers is a universal aim, as value is determined by them. In fact, lean manufacturing begins with a focus on customers' desires and an organization should drive out activities that do

Table 5: Average Mean Score and Standard Deviation of Each Key Area

Key Areas	Average Mean	Std. Deviation	Rank
Customers	4.25	0.663	1
Management and Culture	4.114	0.614	2
Safety and Ergonomics	3.871	0.656	3
Material Handling	3.826	0.861	4
Employees	3.773	0.715	5
Work Processes	3.741	0.752	6
Inventory	3.693	0.861	7
Tools and Techniques	3.655	0.762	8
Equipment	3.598	0.894	9
Layout	3.489	0.695	10

not add values from their perspectives. A greater customer satisfaction would enable a larger market share to be obtained (Katayama and Bennett, 1996).

The high degree of implementation in management and culture reveals that most of the companies were committed in adopting lean manufacturing. In order to achieve success in the initiative, support from management is crucial. It is also important to create a culture where knowledge associated with lean manufacturing is shared across the organization. When knowledge is shared, it becomes cumulative and embedded within an organization's processes and services (Demarest, 1997; and Wong and Aspinwall, 2006).

The low adoption of lean manufacturing practices in product design might be due to many of the organizations were contract manufacturers and subsidiary companies that did not design their product. Therefore, they had no formal system which emphasized on product design. As a whole, the respondent companies were all "moderate-to-extensive" implementers of lean manufacturing because the overall average mean score obtained was 3.658.

Another important area worth exploring was whether there was any significant difference between SMEs and large companies with regard to their level of lean manufacturing implementation. A two-sample, non parametric Mann Whitney test was used to compare the two respondent groups for each of the key areas. The advantage of using a non parametric test is that the data do not necessarily need to be normally distributed. As shown in Table 6, significant differences ($p < 0.05$) were found in a few key areas namely, scheduling, inventory, work processes, employees, safety and ergonomics, and tools and techniques. Specifically, the average mean scores for large organizations were significantly higher than those for SMEs. This implies that large companies have implemented lean manufacturing practices to a greater extent than their smaller counterparts in the six key areas above. This is justifiable because large companies have more resources and a broader range of expertise within their organizations (Doolen and Hacker,

Table 6: Mann Whitney Test for the Degree of Implementation Between SMEs and Large Companies

Key Areas	SMEs	Large Companies	*p*-value	Result
Scheduling	3.02	3.66	0.013	Sig.
Inventory	3.43	3.82	0.042	Sig.
Material Handling	3.76	3.86	0.247	Not Sig.
Equipment Work	3.40	3.69	0.342	Not Sig.
Processes Quality	3.27	3.96	0.005	Sig.
Employees	3.05	3.53	0.120	Not Sig.
Layout	3.45	3.93	0.012	Sig.
Suppliers	3.50	3.48	0.937	Not Sig.
Customers	2.90	3.33	0.060	Not Sig.
Safety and Ergonomics	4.26	4.20	0.907	Not Sig.
Product Design Management and	3.50	4.04	0.005	Sig.
Culture Tools and	2.81	3.34	0.086	Not Sig.
Techniques	4.13	3.97	0.630	Not Sig.
	3.20	3.79	0.006	Sig.

2005; and Wong, 2005) to deploy these areas which are more challenging. In addition, large companies are likely to be overseas subsidiaries of multinational companies (Wong, 2008) that have implemented lean manufacturing.

Ultimately, the respondents were asked to rate the degree of successfulness of their lean manufacturing initiative using a four-point scale. Four choices were given which were: not successful, slightly successful, successful, and very successful. Those who selected the last two categories were regarded as companies that had successfully implemented lean manufacturing. In order to test the relationships between successfulness and each of the key areas, Spearman correlation tests were performed. As can be seen in Table 7, all the p values are less than 0.05, thus implying that there is a significant relationship between successfulness and each of the individual key areas. Since all the correlation coefficients are positive, it can be concluded

Table 7: Correlation Between Successfulness and Each of the Key Areas

Key Areas	Spearman's Coefficient	*p*-value
Scheduling	0.591	0.000
Inventory	0.629	0.000
Material Handling	0.514	0.000
Equipment	0.606	0.000
Work Processes	0.701	0.000
Quality	0.598	0.000
Employees	0.587	0.000
Layout	0.420	0.002
Suppliers	0.526	0.000
Customers	0.595	0.000
Safety and Ergonomics	0.583	0.000
Product Design	0.522	0.000
Management and Culture	0.452	0.001
Tools and Techniques	0.601	0.000

that as the level of implementation in any of the areas increases, there is a corresponding improvement in the success of lean manufacturing.

Hence, all the 14 key areas need to be emphasized and none of them should be neglected or overlooked in order to transform an organization into an effective lean enterprise. In essence, they represent a comprehensive list of factors for organizations to deal with when adopting lean manufacturing. This list helps to ensure that all the relevant issues are covered when companies are planning and implementing a lean manufacturing initiative. It also provides a common framework for academics and practitioners to understand and develop the discipline.

CONCLUSION

This paper has provided important insights into the current status of lean manufacturing implementation in the silk production industry in Andhra pradesh, as well as highlighted some associated issues. Firstly, the respondent companies' general backgrounds (e.g., their size, their involvement in lean manufacturing, etc.) have been discussed. The companies are found to have a good understanding of lean manufacturing, and since its implementation, they have gained many benefits such as reduced cost and improved productivity. It is also apparent that the companies have implemented various tools and techniques to support lean manufacturing, and they do not adopt a single tool in isolation. In order to assess the extent to which they have implemented lean manufacturing, 14 key areas or factors which comprehensively characterize the discipline have been evaluated. Overall, it is shown that the respondent companies are "moderate-to-extensive" adopters of these key areas, but the degree of implementation varies among organizations. Large companies are found to have implemented a few areas more rigorously as compared to SMEs. In addition, statistical analysis shows that individually, each of the 14 key areas has a significant positive relationship with the success of lean manufacturing. Therefore, companies in the silk production industry need to give attention to the implementation of all the key areas from a holistic perspective. It is hoped that the information accrued from this article will trigger more studies to be conducted in lean manufacturing.

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