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An analysis of the status of resource flexibility and lean manufacturing in a textile machinery manufacturing company

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Abstract

Purpose – As the manufacturing industry is under pressure to face the global competition, it is necessary to improve productivity and reduce costs through minimization of wastage of resources for their survival. This paper aims to present an analysis of the status of resource flexibility and lean manufacturing through conducting a case study in an Indian textile machinery manufacturing company and also demonstrate the various areas of future scope for improving lean manufacturing.

Design/methodology/approach – The case study has been conducted using the flexible system methodology (FSM) framework (Sushil, 1994). For measuring resource (labour and machine) flexibility and lean manufacturing, various factors contributing towards labour flexibility, machine flexibility and lean manufacturing are identified. To determine their relative weights, an analytical hierarchy process (AHP) has been used. A specially designed questionnaire is used to collect the information during case study on different aspects of resource flexibility and lean manufacturing. SAP-LAP analysis has also been carried out to look in to the ways the company is building up resource flexibility and lean manufacturing.

Findings – The status of labour flexibility, machine flexibility and lean manufacturing is merely 49.30, 47.10 and 47.40 per cent, respectively. The most important factors of labour flexibility and machine flexibility attained a value of 59.50 and 61.17 per cent, respectively. Similarly, only 39.09 per cent wastes are eliminated through lean manufacturing. There is a huge scope to achieve a higher degree of lean manufacturing through focusing on continuous improvement, just in time (JIT) and resource flexibility factors.

Research limitations/implications – The present study includes only labour and machines to compute the resource flexibility. Other resources may also be included to compute the overall resource flexibility.

Practical implications – The present study provides guidelines to analyze the status of resource flexibility and lean manufacturing. According to conclusions, frail areas in the manufacturing system can be identified and a suitable course of action could be planned for the improvement. Hopefully, this study will help the firm's management to identify the problems to manage resource flexibility and implement an effective lean manufacturing.

Originality/value – In this work, the theoretical perspective has been used not only to update the original instrument, but also to study the subject from a perspective beyond that usually associated with resource flexibility and lean manufacturing.

Keywords Labour, Flexibility, Lean production, Analytical hierarchy process

Paper type Research paper

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1. Introduction

A variety of drivers have an impact on manufacturing, including increased competitive pressures, more demanding customers, shorter product life cycles, shorter times to market and the advent of a great many enabling technologies. Cost management, quality and asset efficiency continue to be important, but other metrics, such as agility, flexibility and speed to market, have become critical. Lean manufacturing has also become more prominent. Lean manufacturing is about more than just cutting costs in the factory. As lean manufacturing became more of a competitive weapon. As a result of these converging manufacturing and flexibility, more and more companies are discovering that traditional strategies for manufacturing no longer support their overall business objectives. Lean manufacturing is a high-velocity order-to-delivery process that many manufacturers have successfully used to improve the overall business performance. In an environment that uses this process, inventory is "pulled" through each production work centre only when needed to satisfy a customer requirement. This means the entire organization must be configured for maximum flexibility and a quick response so that custom orders can be filled as quickly as standard orders. Flexibility can be used not only for effectively managing the changes but also for enhancing the performance of manufacturing systems (Cox, 1989). In addition to knowing which types of flexibility to monitor and how each may be useful, management also needs to understand that there are different ways to implement each type of flexibility. Very little work, however, has been done so far on this issue of flexibility implementation. As pointed out earlier, most studies have assumed or implied that flexibility can only be acquired through capital investment in new machinery. But, in practice, firms use various mechanisms to improve their levels and types of flexibility. Resource flexibility in the form of labour and machine flexibility can be judiciously exploited towards reduction in wastage of resources of a manufacturing enterprise to achieve lean manufacturing (Malhotra and Ritzman, 1990). This paper presents a case study of assessing labour and machine flexibility to implement lean manufacturing in a textile machinery manufacturing company.

2. Literature review

Lean manufacturing evolved out of lean thinking, the antidote to waste (muda). Waste specifically means any activity that absorbs resources but creates no value. Lean thinking provides a way to specify value, line up value-creating actions in the best sequence and conduct these activities with less human effort, less equipment, less time and less space, while coming closer and closer to providing customers with exactly what they want (Womack *et al.*, 1996). Lean manufacturing is not a panacea to solve short-term competitive problems, and its effects can only be seen in the long term (Soriano-Meier and Forrester, 2002). Leanness has undergone and still undergoing a process of continuous and never-ending evolution (Papadopoulau and Ozbayrak, 2005). Lean manufacturing is a systematic approach for identifying and eliminating the waste in operations through continuous improvement, reducing operating cost of the system and fulfilling customers' desire for maximum value at the lowest price (Abdulmalek and Rajgopal, 2007). Lean manufacturing decreases the time between a customer order and shipment. It is designed to improve profitability, customer satisfaction, throughput time and employee motivation (Puvanasvaran *et al.*, 2008). Management commitment and the ability of the change agents are the key determinants of lean manufacturing success

(Herron and Hicks, 2008; Puvanasvaran *et al.*, 2009). There is a significant relationship between lean manufacturing practices and inventory turnover (Demeter and Matyusz, 2010; Eroglu and Hofer, 2011). Waste elimination and JIT are the most important components of lean performance (Behrouzi and Wong, 2011). Staats *et al.* (2011) realize that lean software projects perform better than non-lean software projects for most performance outcomes. Cyclical scheduling fits well in a lean improvement approach in semi-process production and helps to realize regularity in the continuous part of production (Pool *et al.*, 2011). Lean manufacturing and environmental management practices are synergistic in terms of their focus on reducing waste and inefficiency. However, lean manufacturing by itself will not improve environmental performance, because there is a potential for conflicts between environmental performance objectives and lean manufacturing principles (Yang *et al.*, 2011). Chiarini (2011) describes a guideline for integrating ISO 9001 and lean thinking. He finds that, in general, lean thinking implementation affects ISO 9001 documentation, such as quality manual, procedure and work instructions. Furthermore, lean implementation tools and principles are most commonly used in ISO 9001-certified companies. Accuracy of value stream accounting depends on the maturity of lean tools implementation. Normally, when a company starts implementing lean, wastes such as defectiveness, transportations and inventories are relevant and affect activities that cannot be easily transformed into direct costs for the value streams. Value stream has to be extended to the design of product and process, marketing, quality, purchases, shipping and so on (Chiarini, 2012). Mostafa *et al.* (2013) have proposed a phase-wise project-based framework for lean manufacturing implementation. Appropriate practices and decision tools are also proposed and assigned to each phase. Bhamu and Sangwan (2014) have found that simultaneous adoption of leanness in supply chain is a critical factor in the implementation of lean manufacturing. Thus, the implementation of lean manufacturing has become an integrated system composed of highly integrated elements and a wide variety of management practices.

Flexibility is the exercise of free will or freedom of choice on the continuum to synthesize the dynamic interplay of thesis and antithesis in an interactive and innovative manner, capturing the ambiguity in systems and expanding the continuum with minimum time and efforts (Sushil, 1997). Labour flexibility is the ease of moving personnel to different departments of an organization and it is achieved by the aptitude of multi-trained staff to carry out a wide variety of tasks (Treleven, 1989; Tsourveloudis and Phillis, 1998; Singh, 2008). Labour flexibility reduces the manufacturing cost by reducing cycle time and efficient use of resources (Polakoff, 1991). Lean manufacturing is achieved based on measuring the effects of flexibility, the capability of exploiting the resources and adaptability by combined control and management of the product and production processes (Acaccia *et al.*, 1995). Machine utilization and factor productivity increase by the introduction of commonality to the existing system (Nagarur and Azeem, 1999). Traditional forms of labour flexibility need to evolve when technological capabilities are more fully exploited (Karuppan and Ganster, 2004). Labour levels can be reduced to a level without affecting key performance levels (Neureuther and Schikora, 2006). The human factor plays an important role in ensuring lean process management (Puvanasvaran *et al.*, 2008). Labour and machine flexibility positively and significantly contributes towards lean manufacturing (Singh, 2008; Chauhan *et al.*, 2009, 2010). A firm may benefit more from a good mix of both labour and machine flexibility than from an exclusive use of single flexibility (Francas *et al.*, 2011). Stone (2012) evolved out the five phases for performance improvement in order starting with the discovery phase, dissemination phase, implementation phase, enterprise phase and the most recent phase of performance. In general, firms pursuing high divisions of labour, and therefore fostering specialized skills in their workers, will tend to be less flexible than firms relying on a more broadly trained worker who can adapt more quickly to new products or product changes, or to new technologies. Thus, resource flexibility (labour and machine) is an essential requirement for lean manufacturing implementation.

3. Research methodology

A detailed case study in an Indian textile machinery manufacturing company has been conducted with an objective to analyze minutely the practices being followed for managing resource (labour and machine) flexibility and to look into the difficulties and constraints being faced by the industry while implementing lean manufacturing in their systems using the FSM framework (Sushil, 1994). For the present study, Koste *et al.* (2004) form the basis for identification of the resource flexibility factors and Soriano-Meier and Forrester (2002) for the lean manufacturing factors. Ten factors contributing towards labour flexibility, seven factors contributing towards machine flexibility and nine factors contributing towards lean manufacturing are selected for the present study as shown in Tables I-III, respectively. Weight of some factors is more than that of the others. To determine their relative weights, analytical hierarchy process (AHP) has been used (Saaty, 1986, 1990). Each factor has been compared with the other factors pair-wise. Three experts, one industrial manager, one senior production executive and one academician, are chosen to cover the different areas and increase the reliability of the AHP. They, however, filled the response in a qualitative scale of very low, low, medium, high and very high as the difference between the importance of two factors.

Table I. Weightage of labour flexibility factors

Serial no.	Factors	Expert I Weight	Expert II Weight	Expert III Weight	Mean Weight
1	Ability of workers to work on different machines (LF1)	0.3455	0.3708	0.3386	0.3516
2	Skill level of workers to perform different jobs (LF2)	0.2061	0.1114	0.1967	0.1714
3	Cost effectiveness of workers over job change (LF3)	0.0229	0.0216	0.0434	0.0293
4	Reliability of workers over job change (LF4)	0.1115	0.1113	0.0979	0.1069
5	Attitude of workers towards change (LF5)	0.0523	0.0469	0.0204	0.0399
6	Productivity effectiveness due to change (LF6)	0.0523	0.1113	0.0434	0.0690
7	Co-operation of workers in achieving production targets (LF7)	0.0228	0.0469	0.0434	0.0377
8	Ability of production workers to perform inspection jobs (LF8)	0.0523	0.0469	0.0979	0.0657
9	Ability of production workers to do autonomous maintenance (LF9)	0.1115	0.1113	0.0979	0.1069
10	Training of workers (LF10)	0.0228	0.0216	0.0204	0.0216

Table II. Weightage of machine flexibility factors

Serial no.	Factors	Expert I Weight	Expert II Weight	Expert III Weight	Mean Weight
1	Ability of machines to perform diverse set of operations (MF1)	0.4048	0.3886	0.4182	0.4038
2	Machine setup or changeover (MF2)	0.0242	0.0366	0.0509	0.0371
3	Time and effort needed to change the tools and operations (MF3)	0.0995	0.0848	0.0509	0.0784
4	Cost effectiveness of operations over machine change (MF4)	0.0452	0.0366	0.0256	0.0358
5	Productivity effectiveness due to change of machine (MF5)	0.0994	0.0982	0.1126	0.1034
6	Obsolescence rate of machines at introduction of new products (MF6)	0.1798	0.1903	0.2292	0.1997
7	Reliability of machines over job change (MF7)	0.1471	0.1658	0.1126	0.1418

Table III. Weightage of lean manufacturing factors

Serial no.	Factors	Expert I Weight	Expert II Weight	Expert III Weight	Mean Weight
1	Elimination of waste (LM1)	0.3365	0.3588	0.3593	0.3515
2	Continuous Improvement (LM2)	0.0434	0.0462	0.0461	0.0453
3	Zero defects (LM3)	0.0892	0.0999	0.0999	0.0963
4	Just in time deliveries (LM4)	0.1780	0.2045	0.2044	0.1956
5	Pull of raw materials (LM5)	0.0434	0.0462	0.0999	0.0632
6	Multifunctional teams (LM6)	0.1780	0.0999	0.0999	0.1259
7	Decentralization (LM7)	0.0212	0.0223	0.0222	0.0219
8	Integration of functions (LM8)	0.0891	0.0999	0.0461	0.0784
9	Vertical information systems (LM9)	0.0212	0.0223	0.0222	0.0219

These qualitative responses are converted in the quantitative values using the following scale: very low = 1, low = 3, medium = 5, high = 7 and very high = 9. Their contributing weights to labour flexibility, machine flexibility and lean manufacturing are calculated by drawing a position matrix from the experts' response. The weight of each factor has been determined by calculating an eigenvector and normalizing it for each expert's response. To obtain a higher degree of accuracy, the final weightage of each factor of labour flexibility, machine flexibility and lean manufacturing is calculated by taking a mean of the weightage calculated for each expert, as shown in Tables I–III, respectively. A consistency index (CI) and consistency ratio (CR) is also calculated to check the numerical and transitive consistency and validity of experts' judgements for labour flexibility, machine flexibility and lean manufacturing parameters separately.

The data for labour flexibility, machine flexibility and lean manufacturing factors are collected by using a specially designed questionnaire and conducting personnel interaction with employees of different levels. Questions have been framed related to these factors to know the response of the firm to these factors. Labour flexibility, machine flexibility and lean manufacturing have been measured on a 0-1 scale. Multiple regression analysis is also carried out to analyze the contribution of two or more resource flexibility factors to the lean manufacturing. The value of each parameter is calculated as follows:

$$\text{Value of } X_{TH} \text{ Factor} = \left(\sum S_X S_{Max} \right) * W_X \tag{1}$$

Where,

$\Sigma\, S_X$ = Sum of actual score of all questions based upon X_{TH} factor.
S_{Max} = Sum of maximum possible score of all questions based upon X_{TH} factor.
W_X = Weight of X_{TH} factor through AHP.

$$\text{Labour Flexibility (LF)} = \sum\nolimits_{i=0}^{n} LFi * WFi \tag{2}$$

where LF_i is the i_{th} factor value of labour flexibility and WF_i is its weight calculated from AHP.

$$\text{Machine Flexibility (MF)} = \sum\nolimits_{i=0}^{n} MFi * WFi \tag{3}$$

where MF_i is the i_{th} factor value of machine flexibility and WF_i is its weight calculated from AHP.

$$\text{Lean Manufacturing (LM)} = \sum\nolimits_{i=0}^{n} LMi * WFi \tag{4}$$

where LM_i is the i_{th} factor value of lean manufacturing and WF_i is its weight calculated from AHP.

The Situation-Actor-Process and Learning-Action-Performance (SAP-LAP) paradigm of FSM has been used to analyze the case study and to develop a set of guidelines/learnings (Sushil, 2001). Learning issues have been synthesized for developing a system that would improve resource flexibility and help achieve lean manufacturing.

4. Factors' weightage

It is not necessary that all the factors of labour flexibility, machine flexibility and lean manufacturing have equal contribution towards labour flexibility, machine flexibility and lean manufacturing, respectively. The impact of one may be greater than that of the other. So, AHP described by Saaty (1986, 1990) has been used for finding out the weight of each factor towards labour flexibility, machine flexibility and lean manufacturing, respectively. Each factor has been compared with the other factors pair-wise. The experts compared the factors on a qualitative scale of very low, low, medium, high and very high as the difference between the importance of two factors. They, however, filled the response in quantitative terms by converting the qualitative response using the following scale: very low = 1; low = 3; medium = 5; high = 7 and very high = 9. The contributing weights to labour flexibility, machine flexibility and lean manufacturing are calculated by drawing a position matrix from the experts' response. The weight of each factor has been determined by calculating an eigenvector and normalizing it. The weightage of each factor of labour flexibility, machine flexibility and lean manufacturing is calculated by taking a mean of the weightage given by the three experts as shown in Tables I–III, respectively. Reliability and consistency of AHP is tested through calculating the values of CI and CR for all the three experts and for all labour flexibility, machine flexibility and lean manufacturing separately.

The values of CI for the labour flexibility factors are 7.52, 5.06 and 6.66 per cent, and those of CR are 4.98, 3.35 and 4.41 per cent as calculated from the response of the three experts, respectively. The values of CI for machine flexibility factors are 8.92, 5.29 and 7.43 per cent, and those of CR are 9.84, 4.01 and 5.62 per cent as calculated from the response of the three experts, respectively. Similarly, the values of CI for lean manufacturing factors are 7.51, 7.25 and 7.11 per cent and those of CR are 5.17, 5.00 and 4.90 per cent as calculated from the response of the three experts, respectively. All the values are less than 10 per cent, which validates the consistency and reliability of the AHP. As shown in Table I, the most important factor of labour flexibility is "ability of workers to work on different machines" with 35.16 per cent weightage. This has been followed in order by "skill level of workers to perform different jobs" with a weightage of 17.14 per cent, "reliability of workers over job change" and "ability of production workers to do autonomous maintenance" with 10.69 per cent weightage each. Other factors received a weightage of less than 10 per cent, depicting that they are comparatively less important in the calculation of labour flexibility. The ability of workers to work on different machines is significant, as it enables deployment of workers on machines and jobs other than the ones they normally work on. In many organizations, it is a practice now to train the employees on more than one job to achieve this.

Table II shows the weightage of machine flexibility factors. The most important factor of machine flexibility is "ability of machines to perform diverse set of operations" with 40.38 per cent weightage. This has been followed in order by "obsolescence rate of machines at introduction of new products" with 19.97 per cent, "reliability of machines over job change" with 14.18 per cent and "productivity effectiveness due to change of machine" with 10.34 per cent weightage. Other factors which received a weightage of less than 10 per cent are "time and effort needed to change the tools and operations" (7.84 per cent), "machine set-up or changeover" (3.71 per cent) and "cost effectiveness of operations over machine change" (3.58 per cent).

The weightage of the lean manufacturing factors is shown in Table III. The most important factor of lean manufacturing is "elimination of waste" with 35.15 per cent and followed in order by "just in time deliveries" with 19.56 per cent and "multifunctional teams" with 12.59 per cent weightage. Other factors received a weightage of less than 10 per cent, depicting that they are comparatively less important in the calculation of lean manufacturing. The elimination of waste is significant, as it enables the utilization of resources and the maximization of productivity of an organization.

5. The case study

A detailed case study has been conducted at Friends Engineering Works (FEW) located at Sanoli Road, Panipat (Haryana). It manufactures textile manufacturing machinery, e.g. semi-automatic power loom, flexible rapier loom, drop box, dobby, jacquard, warping machine, winder, jute loom and associated accessories. FEW was established in the year 1984 for repairing and job work of textile manufacturing machinery. The company had started manufacture of textile manufacturing machinery with its own brand name "Friends" in the year 1986. The company is duly approved by the Ministry of Textiles (Government of India). The company is also a member of Textile Machinery Manufacturer's Association and Indian Textile Accessories & Machinery Manufacturer's Association. The present production capacity of the company is more than 70 semi-automatic power looms, 70 drop boxes, 10 dobby, 3 warping machines, 2 jacquards, 2 winders and accessories per month. It is an ISO 9001:2008-certified company. The company is awarded by the International Textile Technology and Machinery Expo at Coimbatore, India, in 2006.

5.1 Status of labour flexibility

M/s FEW has a dedicated workforce of 90, out of which one is a manager, one is an assistant manager, four are supervisors, 45 skilled, four semi-skilled and 35 are unskilled workers. About 59.50 per cent of the workers have been trained to work on different machines within the shop. So in case of absenteeism, there is generally no problem of shifting the workers from one machine to another within the shop. About 82.15 per cent of skilled workers are able to handle different types of jobs with the same ease and efficiency. Only 30.71 per cent of the employees have multiple skills and are cost effective. Most of the workers are not able to show good levels of productivity when performing jobs other than their routine jobs. They have been adequately trained, but they do not have a very positive attitude towards job change. The prospects of production employees performing inspection jobs and taking up autonomous maintenance are not high. The overall labour flexibility 49.30 per cent (Table IV).

5.2 Status of machine flexibility

The plant consists of three machine, two planer and two grinding shops, and one shop each of welding, assembly, pattern and foundry. The company is equipped with 12 lathe machines, two hydraulic presses, two planers, four milling machines, one facing machine, three shaper machines, eight drill machines, one surface grinder, four bench grinders, five hand grinders, four welding machines and one bending machine. In machine shops, out of 28 machines, eight are special-purpose machines and 20 are general-purpose machines. The company has procured advanced technological special-purpose side and face planer for the machining of brackets of power looms to

Table IV.
Measurement of labour flexibility

Serial no.	Factor	Questionnaire	Interaction	Average	Achievement (%)
1	LF1	0.2051	0.2133	0.2092	59.50
2	LF2	0.1371	0.1445	0.1408	82.15
3	LF3	0.0117	0.0063	0.0090	30.71
4	LF4	0.0428	0.0367	0.0397	37.14
5	LF5	0.0080	0.0043	0.0061	15.29
6	LF6	0.0276	0.0209	0.0243	35.22
7	LF7	0.0212	0.0204	0.0208	55.17
8	LF8	0.0131	0.0070	0.0101	15.37
9	LF9	0.0214	0.0107	0.0160	14.97
10	LF10	0.0171	0.0169	0.0170	78.70
Labour flexibility		0.5051	0.4811	0.4930	49.30

increase the production rate. In the welding shop, all the four welding machines are general purpose. Over 61.17 per cent machines are general-purpose machines and capable of performing different set of operations. The special-purpose machines also have some machine flexibility and can handle the parts of various sizes. About 60.92 per cent of the machines have easy setup and changeover from one operation to another. Low effort and less time to change the tools is required for 56.63 per cent of machines. Due to change of operations, 13.41 per cent of the same-type machines are not cost effective. Furthermore, 59.19 per cent machines are equally productive and are capable of producing new products also. About 13.05 per cent machines are equally reliable over job change. The overall machine flexibility is calculated to be 47.10 per cent as shown in Table V.

5.3 Status of lean manufacturing

Table VI shows the values of various factors of lean manufacturing calculated through the case study. The case study depicts that M/s FEW has achieved only 47.40 per cent lean manufacturing. The case study results depict that only about 39.09 per cent of the total seven wastes are eliminated and 39.07 per cent of continuous improvement is achieved at FEW. Over 56.70 per cent zero defects are achieved through mounting fixtures and verification gauges on few machines. No scientific method is used to monitor the inventory levels, and only 40.85 per cent is achieved. Through implementing small batches in some areas, 44.94 per cent pull of raw materials is achieved. About 60.84 per cent multifunctional teams are developed for the optimum utilization of human factor. Over 40.64 per cent decentralization is achieved by

Serial no.	Factor	Questionnaire	Interaction	Average	Achievement (%)
1	MF 1	0.2423	0.2517	0.2470	61.17
2	MF 2	0.0223	0.0229	0.0226	60.92
3	MF 3	0.0470	0.0418	0.0444	56.63
4	MF 4	0.0036	0.0060	0.0048	13.41
5	MF 5	0.0103	0.0207	0.0155	14.99
6	MF 6	0.1198	0.1165	0.1182	59.19
7	MF 7	0.0158	0.0213	0.0185	13.05
Machine flexibility		0.4611	0.4808	0.4710	47.10

Table V. Measurement of machine flexibility

Serial no.	Factor	Questionnaire	Interaction	Average	Achievement (%)
1	LM 1	0.1318	0.1429	0.1374	39.09
2	LM 2	0.0181	0.0174	0.0177	39.07
3	LM 3	0.0530	0.0562	0.0546	56.70
4	LM 4	0.0782	0.0815	0.0799	40.85
5	LM 5	0.0295	0.0274	0.0284	44.94
6	LM 6	0.0755	0.0776	0.0766	60.84
7	LM 7	0.0073	0.0106	0.0089	40.64
8	LM 8	0.0627	0.0588	0.0608	77.55
9	LM 9	0.0088	0.0106	0.0097	44.29
Lean manufacturing		0.4650	0.4830	0.4740	47.40

Table VI. Measurement of lean manufacturing delegating some powers to supervisors. Through quality policy, 77.55 per cent functions are integrated and only 44.29 per cent vertical information systems are adopted in the organization.

6. Multiple regression analysis

The purpose of multiple regression analysis under this section is to identify a set of variables which conjointly contribute significantly towards the criterion variable. A stepwise multiple linear regression analysis enables to know the most relevant variables which account for maximum variance in the criterion from the total set of variables. Multiple regression analysis is a method of analyzing the collective and separate contribution of two or more independent variables "X" to the variation of dependent variables "Y". The square of multiple correlations (R^2) is called the coefficient of determination which shows the proportion of variance of the criterion accounted for by the different predictors. To analyze the collective contribution of two or more factors of labour and machine flexibility as independent variables to the variation of each lean manufacturing factor as dependent variable, a stepwise multiple linear regression is carried out taking each factor of lean manufacturing as criterion variable and all the factors of labour and machine flexibility as predictive variables using SPSS 11.01 software. Further, to test the significance of value of R^2, F values are also calculated through analysis of variance (ANOVA) test. Table VII presents the results of multiple linear regression analysis of various factors of labour and machine flexibility towards lean manufacturing factors and overall lean manufacturing. Out of all the 17 factors of labour and machine flexibility only four factors — "ability of workers to work on

Table VII.
Results of multiple regression analysis

Criterion variables	Predictive variables	Selected variables	Multiple correlation (R)	% attribution (R^2) (%)	*F* value	Significant
LM1	All parameters of resource flexibility	LF1, LF3, LF5, MF4	0.782	61.2	18.518	0.000
LM2		LF1, LF2, LF10, MF1	0.717	51.4	12.404	0.000
LM3		LF1, LF2	0.600	36.0	13.755	0.000
LM4		LF1, LF2, LF5, LF10, MF1	0.803	64.5	16.751	0.000
LM5		LF1, LF4, LF5, LF10, MF1, MF2	0.838	70.3	17.723	0.000
LM6		LF1, LF2, LF10, MF1, MF5	0.851	72.4	24.139	0.000
LM7		LF1, LF8, MF1, MF7	0.763	58.3	16.397	0.000
LM8		LF1, LF2, LF10, MF3, MF6	0.822	67.5	19.119	0.000
LM9		LF1, LF4, LF5, MF3	0.729	53.1	13.300	0.000
LM		LF1, LF2, LF5, LF10, MF1	0.873	76.2	29.527	0.000

different machines” (LF1), “cost effectiveness of workers over job change” (LF3), “attitude of workers towards change” (LF5) and “cost effectiveness of operations over machine change” (MF4) — have emerged to be significant predictors of LM1. Conjoint predictive value of these resource flexibility parameters for elimination of waste is 61.2 per cent. Only four parameters — “ability of workers to work on different machines” (LF1), “skill level of workers to perform different jobs” (LF2), “training of workers” (LF10) and “ability of machines to perform diverse set of operations” (MF1) — have emerged to be the potential predictors for increase in continuous improvement. The analysis depicts that the conjoint predictive value of LF1, LF2, LF10 and MF1 for LM2 is 51.4 per cent. So 51.4 per cent of whatever leads to increase in continuous improvement is attributable to these four parameters. Two variables — “ability of workers to work on different machines” (LF1) and “skill level of workers to perform different jobs” (LF2) — contribute significantly towards achieving zero defects. The value of R^2 illustrates that the conjoint predictive value of these two parameters towards zero defects is 36.0 per cent. Five parameters — “ability of workers to work on different machines” (LF1), “skill level of workers to perform different jobs” (LF2), “attitude of workers towards change” (LF5), “training of workers” (LF10) and “ability of machines to perform diverse set of operations” (MF1) — significantly contribute, 64.5 per cent, towards just-in-time deliveries (LM4). Six variables — “ability of workers to work on different machines” (LF1), “reliability of workers over job change” (LF4), “attitude of workers towards change” (LF5), “training of workers” (LF10), “ability of machines to perform diverse set of operations” (MF1) and “machine setup or changeover” (MF2) — have emerged to be the significant predictors of pull of raw materials (LM5). Conjoint predictive value of these parameters for pull of raw materials is 70.3 per cent. Five parameters — “ability of workers to work on different machines” (LF1), “skill level of workers to perform different jobs” (LF2), “training of workers” (LF10), “ability of machines to perform diverse set of operations” (MF1) and “productivity effectiveness due to change of machine” (MF5) — have emerged to be significant predictors of multifunctional teams (LM6). Collective conjoint predictive value of these parameters for multifunctional teams is 72.4 per cent. Four parameters — “ability of workers to work on different machines” (LF1), “ability of production workers to perform inspection jobs” (LF8), “ability of machines to perform diverse set of operations” (MF1) and “reliability of machines over job change” (MF7) — have emerged to be significant predictors of decentralization (LM7). The collective conjoint predictive value of these parameters for decentralization is 58.3 per cent. Five parameters — “ability of workers to work on different machines” (LF1), “skill level of workers to perform different jobs” (LF2), “training of workers” (LF10), “ability of machines to perform diverse set of operations” (MF1) and “productivity effectiveness due to change of machine” (MF5) — have emerged to be significant predictors of “integration of functions” (LM8). The collective conjoint predictive value of these parameters for LM8 is 67.5 per cent. Four parameters — “ability of workers to work on different machines” (LF1), “reliability of workers over job change” (LF4), “attitude of workers towards change” (LF5) and “time and effort needed to change the tools and operations” (MF3) — have emerged to be significant predictors of “vertical information systems” (LM9). The collective conjoint predictive value of these parameters for vertical information systems is 53.1 per cent. Five parameters of resource flexibility — “ability of workers to work on different machines” (LF1), “skill level of workers to perform different jobs” (LF2), “attitude of workers towards change" (LF5), "training of workers" (LF10) and "ability of machines to perform diverse set of operations" (MF1) — have emerged to be significant predictors of overall lean manufacturing (LM). The collective conjoint predictive value of these parameters for lean manufacturing is 76.2 per cent. It is inferred that 76.2 per cent of whatever leads to support lean manufacturing can be attributed to LF1, LF2, LF5, LF10 and MF1 significantly.

7. SAP-LAP analysis

According to Sushil (2001), the three basic components in the FSM paradigm are: situation, actor and process. They interact flexibly on multiple planes. The actor forms a part of the situation and of the process. The situation is to be managed to an organic order by the actor, which is the industry under consideration, through a self-organizing management process which re-creates the situation. SAP-LAP analysis has been carried out to look into the ways the company is building up resource flexibility. SAP analysis and LAP synthesis of FEW is described as follows:

(1) Situation:
  - Market share of 20 per cent in Indian textile machinery.
  - Plant is located in the textile hub of Panipat.
  - Increased demand of textile machinery in the Indian market.
  - Sufficient number of vendors have developed locally to supply sub components.
  - Changed trend towards reduction in wastes.

(2) Main actors:
  - Managing Partners of FEW as the key decision makers.
  - Flexible and dedicated managers and supervisors of the company.
  - Customers of FEW as a guiding force.

(3) Process:
  - FEW has installed latest technology special-purpose planer in 2009.
  - Strengthening quality standards by the ISO-9001:2000 certification in 2005 and upgraded to the ISO-9001:2008 certification in 2009.
  - Shortening of the procurement time from the vendors.
  - Approved by the Ministry of Textiles (Government of India), Mumbai, since 2001.
  - Member of Indian Textile Accessories & Machinery Manufacturer's Association, since 2004.
  - Member of Textile Machinery Manufacturer's Association, since 2005.
  - Awarded by International Textile Technology and Machinery Expo. (ITGME) at Coimbatore, India, in 2006.

(4) Learning issues: Based on the detailed study and analysis of the initiatives taken at FEW to fight competition and survive in the era of globalization and liberalization, following learning issues have emerged:

- Market competition has increased tremendously as a result of globalization and liberalization and resulted in competitive prices. This has compelled the organizations to adopt cost-cutting and lean manufacturing in a big way.
- Acquisition of computerized numerically controlled (CNC) machines and equipment helps in increasing machine flexibility, which contributes towards lean manufacturing.
- Cross-training of workers on different machines improves ability of workers to work on different machines and also their skill levels contribute towards waste elimination, continuous improvement, zero defects, multifunctional teams and total lean manufacturing.
- Acquisition of general-purpose machines increases the ability of machines to perform a diverse set of operations, which contributes towards lean manufacturing.
- Mounting of fixtures, star knobs, locking levers and verification gauges on machines reduces the set-up time, which contributes towards lean manufacturing.
- Implementation of scientific inventory management system helps in better space and capital utilization and improves in machine utilization.
- There is a lot of scope for cost-cutting through strategies like reducing waste, more automation, better discipline, reducing inventory turnover ratio and reduced changeovers.

(5) Suggested actions:
- Plan better capacity utilization of its existing manufacturing facility.
- Cost-cutting innovations should be a regular feature.
- Capabilities and creativity of the people should be explored in parametric research.
- Take up value engineering projects to further slash the cost.

(6) Expected performance:
- Implementation of lean manufacturing will reduce the wastage of resources.
- Development of sustainable competitive advantage through flexible resources.
- Higher customer satisfaction by way of innovation to meet local needs.
- Active on the technology front and emerge out with continuous improvement.
- Development of a flexible workforce contributes towards the optimum utilization of resources.

8. Conclusion

Resource flexibility enables to meet the customers' demands quickly, provide a broad product range or introduce new products to the range easily. The status of labour flexibility and machine flexibility is 49.30 and 47.10 per cent, respectively, at FEW. The company has focused on the skill level of workers to perform different jobs at levels as high as 82.15 per cent through centring on the regular training of workers at a level of

78.70 per cent. Cost effectiveness of workers over job change is attained at a level of 30.71 per cent. The workers cooperate 55.17 per cent in achieving production targets, and 59.50 per cent workers are able to work on different machines. Furthermore, 37.14 per cent workers are reliable over job change. Only 14.97 per cent of production workers are able to do autonomous maintenance, and 15.37 per cent production workers are capable of doing inspection. However, only 15.29 per cent workers have positive attitude towards change, 61.17 per cent machines are capable to perform diverse set of operations, 60.92 per cent machines can be setup or changeover from one operation to other with same ease and 59.19 per cent machines do not become obsolete with introduction of new products. Tools and operations can be easily changed without wasting much time and effort on 56.63 per cent machines. Only 13.05 per cent machines are reliable over job change, and 13.41 per cent machines are not cost effective for same type of operations. Machine productivity varies from machine to machine and only 14.99 per cent machines are capable of performing at uniform productivity. The company has attained a very low level of lean manufacturing (47.40 per cent). The company successfully integrated 77.55 per cent of functions by means of 60.84 per cent multifunctional teams, 40.85 per cent JIT, 44.94 per cent pull of raw materials, 56.70 per cent zero defects and 39.07 per cent continuous improvement to achieve lean manufacturing. The firm is able to eliminate only 39.09 per cent waste from the production system through implementing 40.29 per cent decentralization and 44.29 per cent vertical information systems.

The present study highlights the fact that it is possible to plan for resource flexibility keeping lean manufacturing in mind. Therefore, it is concluded that there is a broad scope to focus upon the strategies which can change the attitude of workers towards change positively. More machines should be installed which have uniform productivity even in the event of change of operations and operators. There is also a huge scope to achieve a higher degree of lean manufacturing by focusing on resource flexibility and eliminating different wastes from the manufacturing system.

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