Change Processes towards Flexible Lean Manufacturing: A Framework

GULSHAN CHAUHAN1, *, T. P. SINGH2 and S. K. SHARMA3

1Dept. of Mech. Engg., Panipat Institute of Engg. & Tech., Panipat, Haryana, India.
2Dept. of Mech. Engg., Thapar University, Patiala, Punjab, India.
3Dept. of Mech. Engg., National Institute of Technology, Kurukshetra Haryana, India.

(Received on October 22, 2008, revised September 09, 2009)

Abstract: To be successful in today’s increasingly time-sensitive and competitive markets, businesses need manufacturing processes that are fast, flexible, and adapt quickly to change. By means of a survey conducted in the Indian manufacturing industries discusses the most important parameters of lean manufacturing and flexibility and the significant benefits that were accrued in flexible and lean manufacturing operations. The flexibility is recognized as an important feature in manufacturing. However, the extent of such technology applications varies from industry to industry and has met various degrees of success. The manufacturing companies that are changing processes towards hybrid flexible lean manufacturing (FLM), and focusing on company strategy for cost reduction through eliminating wastages are remain to sustain in this competitive world. This paper describes the development and comparison of characteristics framework by means of which organizations can effectively integrate and change processes towards FLM. The data for this survey were collected through interviews, questionnaire and archival sources.

Keywords: Flexible lean manufacturing, cost reduction, waste elimination, manufacturing road map, technology impact.

1. Introduction

To be successful in today’s increasingly time-sensitive and competitive markets, businesses need manufacturing processes that are fast, flexible, and adapt quickly to change. Over the past decade, competitive businesses have worked hard to reduce the amount of “capacity plump” and “inventory plump” in their manufacturing systems. These initiatives have led to remarkable improvements in operational efficiency and the emergence of today’s increasingly lean and responsive manufacturing systems. This is an important step towards competitiveness. But to achieve full competitive status, a company must integrate its manufacturing strategies into its manufacturing operations. Companies that control their assets productively are capable of generating higher-than-normal returns.

Some of the world’s leading companies (known for their lean production philosophy) have been utilizing their manufacturing competence to generate financial benefits. As manufacturing system continue to become leaner and the level of plump (inventory, capacity, labor) continues to drain, companies whose manufacturing capabilities cannot respond quickly to variable demands become increasingly vulnerable.
These companies are now searching for ways to integrate all their manufacturing activities. But the majority of point solutions available to help them address this problem are inadequate to the task because they work only in much localized environments and fail to have wide industry application. That’s why, to date, most manufacturing systems have focused on generating savings through waste minimization and lean manufacturing. Greater savings are possible by linking lean manufacturing to the flexibility. But it is a generalized concept that increase in flexibility increases input cost. Lean manufacturing couldn’t be implemented judiciously without optimizing the flexibility. So, the Lean manufacturing with flexibility is known as the Flexible Lean Manufacturing (FLM): a new concept of manufacturing strategy for today’s competitive environment.

Flexible lean manufacturing enables companies to produce goods efficiently and manage variability proactively. Efficient production requires a system with efficient planning and execution capabilities. Proactive management requires a system that can rapidly sense and respond to any exceptions that impact manufacturing while continuing to incorporate learning into manufacturing processes. To implement FLM process which is continuously adaptive, companies must have:

- Intelligently leverage applications and technology to connect “plan-execute-sense-respond-learn” operations
- Seamlessly link factory processes, production equipment, and factory systems to flexible lean operations

FLM must be managed as an end-to-end, closed-loop process with tight linkages between the manufacturing applications and with adjacent enterprise applications. And most important is the technology that enables these applications across the distributed manufacturing base. Such integrated networks enable the process visibility and collaboration capabilities that are key to building a FLM enterprise.

There is a need to identify the individual processes and the flow of the organization as a whole. This exposes the management and employees to more opportunities to improve the process. The distinctive thing about lean thinking is that it derives from observing the best practices in an organization. Papadopoulou [1] believed that in the present dynamic business nature, leanness has undergone and still going a process of continuous and never ending evolution.

2. Literature Review

In order to meet the changing needs of the consumer, many new methods of flexible manufacturing, new conceptual models, and advanced information technology have been developed and implemented. In recent studies, it has been shown that flexibility in a manufacturing environment can be improved by exploiting manufacturing technologies [2]. Other studies have defined the tradeoffs that exist within and across certain dimensions of manufacturing flexibility [3]. Some studies have examined several types of manufacturing flexibilities that lead to improved performance. Zhang et al. [4] describe a framework for exploring the relationships among flexible competence, flexible capability, and customer satisfaction. In addition, several studies have evaluated manufacturing environments and have determined specific factors for achieving flexibility from a manufacturing perspective. Petroni and Bevilacqua [5] conducted a questionnaire survey in which they examined seven basic dimensions of manufacturing flexibility to identify manufacturing flexibility best practices in small and medium enterprises.

Manufacturing flexibility is often construed as the ability to respond quickly to change with minimum penalty [6, 7]. Despite being touted as an important strategic weapon, flexibility is not formally managed like quality and cost [8]. The most impressive
impact of increasing flexibility is a reduction in inventory [9, 10]. Bobsowski and Park [11] obtained reduction in flow time when workers were able to move across machine centers. Fryer [12] noted that interdepartmental transfers were more effective than intradepartmental transfers in causing flow time to decrease. A multi-skilled workforce is believed to enhance system performance [13]. Mohamed [14] and Cagliano and Spina [15] reported that strategically flexible production by itself and combined with computer integration reduced delivery lead time. Kruppan and Ganster [16] suggested that the simultaneous pursuit of multiple competitive priorities is indeed possible but requires some compromises in the alignment of resources.

The objective of new technological systems is to simplify the flow of activities to improve organizational outcomes such as cost, quality, and lead time [17]. According to two researches conducted by Boyer [18] and Soriano-Meier [19], there are two major issues that will influence the implementation of lean manufacturing in an organization. They are management commitment to lean manufacturing and manufacturing infrastructure investment. Puvanasvaran et al. [20] reveals and indicates the importance of introducing lean process management for the organization to sustain and be more productive and profitable. Franchini et al. [21] suggested that industrial managers should assign operators with a high level of skills first and assign versatile operators last if they wanted to maximize quality and minimize staffing costs. This would mean that competing simultaneously on the basis of flexibility, quality, and cost would require trade-offs. Flexible automation may blur the distinctions between cost, quality, delivery, and flexibility through the synergistic impact of increased productivity, speed, and variety when it is properly implemented [22].

3. Manufacturing Challenges

Despite significant improvements in manufacturing efficiencies over the years, producing to near real-time demand is easier said than done: especially in a business environment where variability is continually increasing. Some of the factors responsible for this increase in variability are:

- **Fragmented manufacturing facilities**: Globally distributed manufacturing locations are increasing exponentially, demanding new manufacturing visibility and collaboration.
- **Mass customization**: The rapidly increasing cross-industry demand for product variety presents challenges in areas such as manufacturing capacity and resource planning.
- **Shrinking life cycles**: Product life cycles are rapidly shortening, and pose challenges in areas such as manufacturing cycle time, productivity, and inventory management.
- **Response velocity**: Customer empowerment is driving managers to target new levels of flexibility, leading to higher manufacturing capacity costs and labor deployment challenges.
- **Zero defect quality**: Product quality requirements are becoming increasingly stringent, causing manufacturers to focus on “Zero Defect” production capabilities. These challenges indicate that purely traditional manufacturing practices, which were based on the push and made-to-stock philosophy with little visibility to true demand, will not succeed in the current business environment. Manufacturers will have to transition to operating in a continuously adaptive mode.

4. Manufacturing Road Map: From Push to FLM
Compared to the supply chain revolution of the early 1990s, today’s manufacturing revolution is relatively mature and has seen several phases of transition. It is important to understand that the newer manufacturing practices do not replace the older ones but instead continue to blend the best of the current and past manufacturing practices to meet current business needs. Thus, although various manufacturing philosophies currently exist - push, lean, flexible: none are applied in a pure, holistic fashion. Most companies run a hybrid system.

4.1 Push Manufacturing

The 1970s was the era of push manufacturing. At that time it was still a sellers’ market for the most part, and companies were focused primarily on building capacity and maximizing production throughput. Product variety was no where near the challenge it is today, and almost all that was produced was built to forecast. This was the era that also saw the real emergence and popularity of material requirements planning (MRP), which recognized as a key tool for enhancing productivity.

4.2 Lean Manufacturing

The push manufacturing decade was followed by the lean manufacturing era. Popularized by the Japanese as just-in-time (JIT) or pull manufacturing, the principle focus of the lean manufacturing philosophy was to minimize all forms of waste and produce quality products. Rework was considered the worst waste of all, and one of the primary metrics of lean manufacturing was “first pass” quality. Not surprisingly, the greatest impact of lean manufacturing was in the reduction of waste. The philosophy worked well in an environment of low product variability and relatively stable customer demand.

4.3 Flexible Manufacturing

The late 1980s and early 1990s witnessed the emergence of flexible manufacturing practices. This post industrial phenomenon was a response to more volatile markets, higher product proliferation, shorter life cycles, quicker response capabilities, and more sophisticated buyers. All of these factors increased business complexity significantly and led to the breakdown of the lean principles that focused on stable demand and relatively low product variation. In this new environment, responsiveness and product availability were key to maintaining sales and market share. Flexibility became the new strategic imperative. Flexible manufacturing exploited the gain from product proliferation and mass customization to reach economies of scope. Flexible manufacturing practices also popularized the concepts of general-purpose machines and equipment, cross-trained workers, information technology, well-developed vendors, and a highly trained indirect staff. But flexible manufacturing was not without its flaws, chief among them being the cost of flexibility. Companies came to realize that although some excess flexible capacity allowed better management of variability, outsourced manufacturing was often a more viable means to the same end.

4.4 Flexible Lean Manufacturing

An enterprise production system must be designed to achieve the goals of cost, quality, flexibility and delivery time simultaneously [23]. The efficiency benefits of push manufacturing, the quality and cost benefits of lean manufacturing, and the responsiveness benefits of flexible manufacturing have all become plain market qualifiers. FLM in the hybrid form is the key characteristic driving this success. FLM has three primary characteristics, flexibility, leanness and velocity. Flexibility enables a
manufacturing unit to scale efficiently while velocity determines its ability to switch operational modes rapidly. FLM enterprises are expected to achieve required flexibility and velocity by linking lean technology to factory processes, production equipment, and factory systems. This integrated technology will allow them profitable manufacture of products for increasingly time-sensitive and competitive markets. FLM influences technology to build hybrid-manufacturing capability that benefit from the best practices of all manufacturing processes.

![Figure 1: Illustration of a Traditional and FLM Process](image)

5. **Research Methodology**

In traditional mass manufacturing, there were specialized workers and machines that were managed. Today manufacturing on the other hand need flexible workforce and machines. The firms where the manufacturing flexibility is higher are generating less amount of wastage of resources. The survey was carried out in manufacturing industry of India. The methodology adopted includes the following:

(a) Design of a questionnaire covering various parameters of manufacturing flexibility and lean manufacturing and it’s pre-testing by taking response.

(b) Collection of information by taking response in questionnaire and through personal visits.

(c) Analysis of information and assessing the following:

   (i) Status of manufacturing flexibility in each company.

   (ii) Status of lean manufacturing in each company.

   (iii) Co-relation between manufacturing flexibility and lean manufacturing of each company.

6. **Scale Development**

A questionnaire was specially designed to collect information on various parameters of manufacturing flexibility and lean manufacturing. These parameters of manufacturing flexibility and lean manufacturing are given in table no. 1 and Table no. 2 respectively along with their codes. The codes have been used for carrying out statistical analysis of the collected data. Seven point likert-type scales were used for the manufacturing flexibility and lean manufacturing items. The scales ranged from “strongly disagree” to “strongly agree”, with a middle anchor point of “neither agree nor disagree”.
A convenient sample of twelve firms, with the desired characteristics, was selected for the pretest of the questionnaire. Potential respondents were contacted, told the subject of the study, and requested to participate. The instrument was completed by a total number of 52 organizations. In addition to completing the survey, the respondents provided written qualitative feedback on clarity of both the instructions and the survey items. The respondents provided notes and comments on any words or items that were ambiguous or imprecise. Prior to finalizing the instrument, a thorough review of all the survey items was undertaken and changes were made. Status of manufacturing flexibility and lean manufacturing was found out from the levels of different parameters implementation.

Each question on MF and LM had seven options and thus a score between one to seven awarded. Table 3 and Table 4 depicts the average scores of various parameters of MF and LM respectively on a scale of 0 to 1. These scores have been worked out from the raw scores collected from the response of the questionnaire using the following formula [24].
Average Score = \( \frac{\sum S_{ai}}{n S_{mi}} \), where \( S_{ai} \) is the average score of a sub area, which is further equal to \( \frac{\sum S_{i} N_{j}}{N} \), where \( S_{i} \) is the score of a company in a sub area (i varies from 1 to 7), \( N_{j} \) is the number of companies securing that score, where \( \sum j = N \), total no. of companies and \( S_{mi} \) is the maximum score of a sub area i.e., 7.

6. Relationship of Manufacturing Flexibility and Lean Manufacturing

From the data collected average score of each parameter of MF and LM for each of the 52 companies have been worked out. Average score of each company in various parameters of MF and LM also calculated. The average value of status manufacturing flexibility and lean manufacturing of the surveyed Indian industry is calculated as 0.63 and 0.61 respectively.

Table 3: Correlation between Various Parameters of MF and LM

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MF1</td>
<td>.36**</td>
<td>.52**</td>
<td>.47**</td>
<td>.47**</td>
<td>.49**</td>
<td>.60**</td>
<td>.67**</td>
<td>.52**</td>
<td>.53**</td>
<td>.66**</td>
</tr>
<tr>
<td>MF2</td>
<td>.27</td>
<td>.48**</td>
<td>.54**</td>
<td>.45**</td>
<td>.37**</td>
<td>.52**</td>
<td>.39**</td>
<td>.59**</td>
<td>.35**</td>
<td>.58**</td>
</tr>
<tr>
<td>MF3</td>
<td>.50**</td>
<td>.28*</td>
<td>.33*</td>
<td>.26</td>
<td>.24</td>
<td>.26</td>
<td>.44**</td>
<td>.10</td>
<td>.45**</td>
<td>.37**</td>
</tr>
<tr>
<td>MF4</td>
<td>.26</td>
<td>.27</td>
<td>.29*</td>
<td>.21</td>
<td>.11</td>
<td>.25</td>
<td>.57**</td>
<td>.25</td>
<td>.58**</td>
<td>.37**</td>
</tr>
<tr>
<td>MF5</td>
<td>.74**</td>
<td>.32*</td>
<td>.38**</td>
<td>.41**</td>
<td>.43**</td>
<td>.32*</td>
<td>.30*</td>
<td>.25</td>
<td>.52**</td>
<td>.48**</td>
</tr>
<tr>
<td>MF6</td>
<td>.55**</td>
<td>.30*</td>
<td>.21</td>
<td>.30*</td>
<td>.26</td>
<td>.25</td>
<td>.53*</td>
<td>.29*</td>
<td>.57**</td>
<td>.43**</td>
</tr>
<tr>
<td>MF7</td>
<td>.44</td>
<td>.07</td>
<td>.045</td>
<td>.12</td>
<td>.17</td>
<td>.10</td>
<td>.42</td>
<td>.01</td>
<td>.37</td>
<td>.20</td>
</tr>
<tr>
<td>MF8</td>
<td>.50</td>
<td>.07</td>
<td>.23</td>
<td>.15</td>
<td>.07</td>
<td>.11</td>
<td>.13</td>
<td>.08</td>
<td>.12</td>
<td>.04</td>
</tr>
<tr>
<td>MF9</td>
<td>.13</td>
<td>.42</td>
<td>.24</td>
<td>.53</td>
<td>.43</td>
<td>.53</td>
<td>.20</td>
<td>.60</td>
<td>.02</td>
<td>.49</td>
</tr>
<tr>
<td>MF10</td>
<td>.42</td>
<td>.61</td>
<td>.41</td>
<td>.71</td>
<td>.75</td>
<td>.69</td>
<td>.53</td>
<td>.49</td>
<td>.32</td>
<td>.73</td>
</tr>
<tr>
<td>MF11</td>
<td>.39</td>
<td>.32</td>
<td>.44</td>
<td>.35</td>
<td>.25</td>
<td>.35</td>
<td>.39</td>
<td>.42</td>
<td>.40</td>
<td>.46</td>
</tr>
<tr>
<td>MF12</td>
<td>.44</td>
<td>.22</td>
<td>.17</td>
<td>.12</td>
<td>.22</td>
<td>.29</td>
<td>.39</td>
<td>.31</td>
<td>.30</td>
<td>.35</td>
</tr>
<tr>
<td>MF13</td>
<td>.55</td>
<td>.15</td>
<td>.19</td>
<td>.60</td>
<td>.12</td>
<td>.04</td>
<td>.29</td>
<td>.01</td>
<td>.54</td>
<td>.16</td>
</tr>
<tr>
<td>MF14</td>
<td>.52</td>
<td>.34</td>
<td>.25</td>
<td>.36</td>
<td>.24</td>
<td>.21</td>
<td>.56</td>
<td>.27</td>
<td>.51</td>
<td>.43</td>
</tr>
<tr>
<td>MF15</td>
<td>.32</td>
<td>.19</td>
<td>.27</td>
<td>.15</td>
<td>.12</td>
<td>.12</td>
<td>.40</td>
<td>.18</td>
<td>.50</td>
<td>.29</td>
</tr>
<tr>
<td>MF16</td>
<td>.64</td>
<td>.42</td>
<td>.20</td>
<td>.43</td>
<td>.32</td>
<td>.22</td>
<td>.54</td>
<td>.12</td>
<td>.48</td>
<td>.44</td>
</tr>
<tr>
<td>MF17</td>
<td>.71**</td>
<td>.47**</td>
<td>.39**</td>
<td>.51**</td>
<td>.44**</td>
<td>.45**</td>
<td>.68**</td>
<td>.43**</td>
<td>.66**</td>
<td>.65**</td>
</tr>
</tbody>
</table>

* Correlation is significant at the P = 0.05 level (2-tailed).
** Correlation is significant at the P = 0.01 level (2-tailed).

The correlation matrix in Table 3 indicates that the P values of co-efficient of correlation between various parameters of HF and LPM are positive and significant. This shows that the factors are complementary to one another. If one becomes better it has a positive effect on other factors and vice-versa. The correlation matrix in Table 4 depicts that manufacturing flexibility is significantly and positively related with lean manufacturing \( (r = 0.645, \text{significant at } p = 0.01) \).

7. Discussion

The various parameters of lean manufacturing significantly and positively related with various parameters of manufacturing flexibility. The weakest correlation is \( (r = 0.01) \) between integration of functions and cost effectiveness of operations over machine change. The strongest correlation is \( (r = 0.75) \) between pull of raw materials and ability of
machines to perform diverse set of operations. Granted, the lean approach is not the solution for all manufacturing problems. But it does offer a uniquely waste minimization solution for more complex manufacturing systems. The ultimate combination of cost reduction and timely delivery of orders is possible only through implementing the FLM. The basic lean manufacturing principles that help to evaluate FLM solutions for manufacturing system applications are continuous flow, lean machines/simplicity, workplace organization, parts presentation, re-configurability, product quality, maintainability, ease of access and ergonomics.

Table 4: Correlation between Manufacturing Flexibility and Lean Manufacturing

<table>
<thead>
<tr>
<th>Correlations</th>
<th>MF</th>
<th>LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF Pearson Correlation</td>
<td>.645**</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>LM Pearson Correlation</td>
<td>.645**</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level

The framework to achieve integrated flexible lean manufacturing system is summarized in Figure 2. Within this framework we focused on the manufacturing flexibility performance characteristics along with the implementation of lean manufacturing principles. The flexibility is balanced and evaluated along with the dynamic reallocation and scheduling in this model. A managerial decision framework usually begins by evaluating the environmental uncertainties of a spirited situation and evaluating them against internal capabilities. Thus to make sense of these environmental uncertainties we must recommend and define the various strengths, weaknesses, opportunities and threats of an organization. A hierarchical relationship of manufacturing flexibility and lean manufacturing is presented to implement flexible lean manufacturing system.

8. Conclusions

It is hard to deny that most of the manufacturing companies that are focusing on company strategy for cost reduction through eliminating wastages are remain to sustain in this competitive world. The study reveals and indicates that the lean manufacturing and manufacturing flexibility is positively and significantly related to each other. Competition is fierce in all aspects of business such as technology, cost, product quality and service. Implementation of integrated flexible lean manufacturing system is the only way out to remain competitive. Therefore, change the processes towards latest FLM appears to be the only solution to survival and definitely becomes their arms to fight to achieve this goal. Implementation of FLM is:

- Not a one off program of the month
- A journey that can take years to successfully implement
- Not just an application of new techniques, it is a new way of looking at the world
- Striving for excellence refers to continuous improvement attitude or approach that a company never becomes perfect or fully flexible and lean
Figure 2: A framework for integrated flexible lean manufacturing system

References


Gulshan Chauhan is an Associate Professor and Head of the Mechanical Engineering Department at Panipat Institute of Engineering & Technology, Samalkha, Panipat. He received his B. E. in Mechanical Engineering from NIT, Kurukshetra and M. Tech. in Industrial Engineering from Punjab Technical University, Jalandhar. His research interests include manufacturing flexibility, lean manufacturing, waste management, productivity improvement, capacity utilization and product development.

T. P. Singh is a Professor in Mechanical & Industrial Engineering Department at Thapar University, Patiala. He received both his M. Tech. and Ph. D. in Industrial Engineering from Thapar University, Patiala. His research interests include manufacturing flexibility, lean manufacturing, waste management, productivity enhancement, technology induction for small scale industry.

S. K. Sharma is a Professor in mechanical engineering department at National Institute of Technology, Kurukshetra. Dr. Sharma received his B. Tech and M. Tech in Production & Industrial Engineering from Thapar University, Patiala, and Ph. D. also in Production & Industrial Engineering from NIT, Kurukshetra. His research interests include waste utilization for power generation, production management, productivity improvement and capacity utilization.