Planning for Flexible Manufacturing

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Abstract

Abstract *– Flexible manufacturing starts from the premise that adding value and reducing waste are the primary goals of any business. It is a philosophy with a series of tools to get to the top and to stay there. But for many still, the teething pains of change and a steep climb are too much to bear and sustain. There are a number of weak points in a company that makes it difficult if not impossible to achieve the promised gains for the efforts they put in. To implement flexible manufacturing requires careful planning. This paper discusses some of the basic issues that companies should consider and follow when transitioning to lean production system.*

Key Words – Flexible manufacturing, kanban, lean manufacturing, setup reduction

I. INTRODUCTION

Companies have adopted flexible manufacturing principles as a way to reduce costs, reduce lead times, improve customer satisfaction, and increase productivity. The process of becoming flexible or agile may mean transforming oneself from one's existing style of operations to an entirely different one. It is a culture and philosophy for an entire enterprise. The process may require significant changes in the functions of the company.

Even though there are many examples of companies that have become more competitive and successful by adopting flexible manufacturing principles and practices, there are many more examples of those who have not been as successful. Many organizations are not clear about what does it take to become flexible or lean. To convert from mass production to lean, they relate flexible manufacturing to kanban system, or reduction of lot sizes from thousands to hundreds, or making a U-shaped cellular layout.

It may not be clearly understood by the companies implementing flexible manufacturing is that kanban or pull system can be used only when it is easy to associate part requirements with the requirements of the finished product. If it is difficult to associate part needs and finished product requirements, then push system is better than kanban system. Although MRP correctly calculates part requirements by precisely associating them with the finished product requirements; but because of (1) combining part requirements into sizable lot sizes and (2) long lead times, the association is no longer correct thereby making a pull system impractical. The lot size and lead time erode the close association between part requirements and the finished product requirements.

Many published articles in this area also, do not completely describe the process of going through the gradual and painful progress towards flexible manufacturing. A number of companies have difficulty achieving even a fraction of the benefits that studies have shown that a lean environment requires half of the hours of human effort spent on production, one-third of the hours of human effort

spent on engineering, half of the factory space to produce the same output with a significant reduction in WIP inventories and defect rate.

This paper presents an approach to understand and apply the intricate principles of flexible manufacturing. It will become easy to apply when the principles are properly understood. The paper will not discuss some of the most basic techniques, namely the 5S, visual factory, total productive maintenance, error-proofing, and multifunctional employees. The paper starts with relationship of flexible manufacturing with the well-known inventory management principles. The next section shows that the inventory management principles that have been well established in theory and practice, actually help develop flexible or lean principles. It's as if the two are sides of the same coin.

II. SOME LEAN MANUFACTURING PRINCIPLES

Generally lean production is considered as a stand-alone concept starting with any application of interest depending on the needs of the industry. However, there exists a natural transition from basic inventory management principles and the development of the concepts of lean production. There is a model called Economic Production Quantity (EPQ) model. Details of this model can be found in any text production or operations management text book [2]. Fig. 1 gives a typical quantity versus time graph for this model. The EPQ is calculated by the square root equation given in the figure where, S=Setup cost per setup, D=annual demand in units, *i*=inventory carrying %/year, P=production cost/piece, *d*=demand rate of the item, *p*=production rate of the item, and ROL = reorder level.

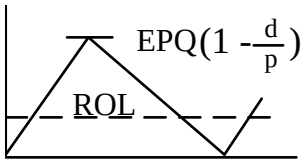


Fig. 1 Basic EPQ model

$$EPQ = \sqrt{\frac{2SD}{iP(1-\frac{d}{p})}} \qquad (1)$$

A. TAKT Time

The maximum inventory that can be reached in this situation is EPQ(1 –*d*/*p*) which can be rewritten as = total production during lead time – demand during lead time. Maximum inventory can be then determined by the relationship.

$$\text{Maximum inventory} = (p-d)\cdot LT \qquad (2)$$

where LT = lead time = EPQ/*p*.

It is clear that if *p-d* increases, inventory increases. In lean manufacturing, the TAKT time is based on the customer demand rate, thus, TAKT time = *d*. A major principle in lean manufacturing is that the production rate should be made equal to the customer demand rate to eliminate the inventory build up, that is, $p = d$.

B. Importance of Lead Time Reduction

From (1), the economic production quantity is infinite when $p = d$, that is the company does not stop production of a product and changeover to the next. The production is continuous and at the same rate to meet the continuous customer demand for the time period the demand occurs.

The maximum inventory given in (2) refers to the excess inventory that is produced in excess of the current requirements, and does not represent the work-in-process (WIP) that is required to run operations.

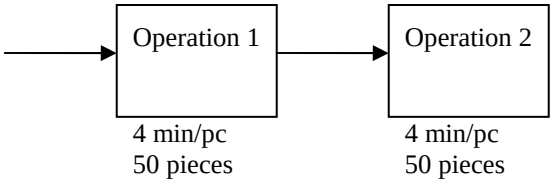
The minimum inventory to run the operations, given $p = d$, is,

$$\text{Minimum inventory} = p \cdot LT \qquad (3)$$

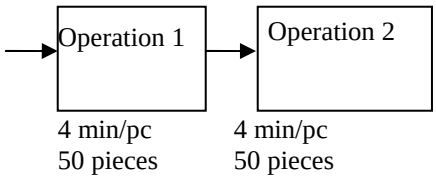
Reducing lead time is critical to minimizing inventory.

If p = 100 per day, and lead time is 10 days, the minimum inventory in the shop is 1,000 units. If the lead time is reduced to 3 days, the minimum inventory is 300 units. Therefore, to reduce WIP, one should concentrate on reducing the production lead time. This is an important principle in lean production. The techniques of lean production are geared to highlight where the lead times are excessive and should be reduced.

Fig. 2 shows how lead times can be reduced by reducing the lot size that is, changing a batch-type production to one-piece flow. In batch production, the utilization of machines in the two operations are unbalanced. Operation 1 is busy with the product whereas operation 2 is not busy



Lead time to finish 50 pieces as a batch is 400 minutes



Lead time to finish 50 pieces in 1-piece flow is 204 minutes

Fig. 2 A method to reduce lead times

with *this* product, and vice-versa, when operation 2 is busy with the product, operation 1 is not busy with it. In one-piece flow, both the operations are busy working on the *same* product.

C. Number of Kanban Containers

If a company has achieved the closeness between finished product requirements and its part requirements, and the WIP is the only inventory, the kanban containers and its size can be easily obtained as given below.

The number of Kanban containers depends on the WIP. It is given by:

$$N = \frac{d \times LT\ (1 + sf)}{cc} \qquad (4)$$

where, *d* and LT have been defined before, and
N = Number of kanban cards or containers
sf = safety factor
cc = container capacity, number of units

D. Reduction of Setup Times

There is a direct relationship between production batch size and setup times [2]. Before batch size and inventory can be taken up for potential reduction, it is necessary to reduce the process setup times. In other words, the batch size should not be arbitrarily reduced without reducing the changeover time. The goal of one-piece flow of lean production can only be achieved when the changeover time is reduced to, say, within 5 minutes or what is commonly known as SMED (Single Minute Exchange of Dies).

In most companies, opportunities to apply lean concepts are abundant. Most companies learn to identify these opportunities by mapping the value stream for each major product type [4]. The value stream consists of all those activities, from forecasting and planning through invoice collection, required to deliver products and services to customers.

The value-stream-mapping process will likely reveal that, from the customer's perspective, a significant amount of non-value adding activities are embedded in the current processes. These are the activities that consume financial and human resources and extend throughput time without adding to the economic value of a product or service.

By mapping value streams, identifying non-value adding activities and focusing on those processes likely to benefit most from the application of lean principles, a company can begin applying lean concepts. However, value stream mapping is just one of the tools in lean manufacturing and after it is successfully applied, companies often find out that there are numerous areas that need improvement.

III. DIFFICULTIES IN IMPLEMENTATION

The sad fact is that the majority of U.S. manufacturers have not adopted lean principles. A recent survey by Industry Week indicates that only about one-third of these companies consider lean manufacturing as their primary improvement program. In fact, industry experts estimate that fewer than 5% of US manufacturing firms are truly lean [3].

A. Large Lot Sizes are Better

Even though lean manufacturing has proven time and again to work, why are not US companies lean? Two major reasons that have been discussed in various industrial forums, will be discussed next. First reason is that that lean thinking is counterintuitive to what US management is taught. Lean manufacturing while proven, does not fit comfortably into the business philosophies. Using economies of scale, people know that more is better. The idea is that if you make large batches of product you have used your equipment more efficiently and reduced the cost per piece, while the cost is not minimized if you make small batches with time-consuming changeovers. In this approach, the focus is on machine and operator efficiency. While in lean manufacturing the focus is on value-added activities and the efficiency of the workflow as a whole. More is not necessarily better. The focus is on to synchronize operations so the entire workflow produces product that customer needs it and in the amount the customer needs it [1]. In lean, the focus is on the overall system and how the system generates value.

B. Lack of Understanding of Flexibility

Second reason for the lack of application of lean manufacturing concepts is the basic lack of understanding of lean principles [6]. It showed that there exists a logical flow of application of lean principles. Even though the management is committed to improve, and the employee involvement is high, but valuable resources are wasted in using the right technique in incorrect sequence.

Generally, in discussions of implementing lean manufacturing, tools such as inventory reduction, lean layout, pull production, or kanban come up first. According to [6], these attractive tools cannot be used in the beginning unless some pre-requisite tools have been successfully applied.

Often times in lean manufacturing literature, statements such as “four key principles of lean manufacturing are value, value stream mapping, pull production, and continuous flow” or similar ones can be found. But as indicated earlier, pull production is counterintuitive to thinking. Various techniques are thrown at a problem situation hoping that some will work and give the benefits that many companies have reported. The obvious result is that the company people who have no time to delve deep into the theory do not achieve the desired results and abandon their effort at least temporarily. By having disturbed from their existing comfort zone, they are unable to find quick settlement in the new paradigm shift of their company culture, they quickly go over to their established old pathways of doing work.

IV. WHAT TO IMPLEMENT?

In this paper, the author proposes based on experience two important tools or concepts that firms can begin their journey towards flexible manufacturing. Besides the basic ones of 5S, visual factory, and multifunctional employees, they are:

(1) Setup reduction or quick changeover, and
(2) Mixed-model or dedicated production.

A. Setup Reduction

It was seen before that before inventory or production lot size can be reduced or before lean layout of one-piece flow can be achieved, it is important to reduce setup.

Setup reduction is number one in the sequence of application of lean manufacturing tools if possible else the next section gives some other alternatives. It is not the intent of the paper to get into the detailed step-by-step procedure for setup reduction which can be obtained from any book on lean manufacturing. When setup times are large like in a batch production, there is higher WIP inventory and the processes are kept unnecessary further apart.

When setup times are reduced, lead times are shortened, batch sizes are reduced, WIP is reduced, and the operations can be brought closer thereby making it easier for people to work in teams on a product line or a cell. This approach leads naturally to one-piece flow, and gives the flexibility to change models on the same line.

It is important to reduce setup in bottleneck operations first. In a bottleneck operation, time saved through setup reduction can be utilized for products waiting for the operation. An increase of throughput rate at bottleneck increases capacity utilization in the whole system.

While in a non-bottleneck operation, time saved through setup reduction may have a tendency to add to the existing idle time as there may not be other products waiting for the operation. Therefore, an increase of throughput rate at a non-bottleneck should involve reallocation of resources from non-bottleneck to bottleneck operations. Once the setup is reduced, many other benefits accrue to a company, and this cycle can be continued till desired level of production flow or benefits of lean manufacturing are obtained.

Teams that have been successful in significantly reducing setup time challenge every activity. One very useful technique for doing this is known as the “5 Whys” from six-sigma methodology. By asking why an activity is performed, and subsequently asking why following each response, it is frequently possible to get to the root of the problem. Understanding root causes of all activities in a setup sets the stage for a successful setup reduction process [3].

B. The Two Production Models

Another important approach that companies can use to get immediate and long-term benefits is to plan ahead to determine whether mixed-model production is suitable for them or dedicated production.

This approach primarily depends on the setup times. If the setup times have been reduced, it becomes easier to change models on an operation, which makes mixed-model approach convenient or cost-effective. On the other hand, if the setup times are not possible to reduce, benefits can still accrue, if dedicated production model is used.

Fig. 3 shows that for the same line, one process may have mixed model and the subsequent process may have dedicated production.

A problem in dedicated model of production can be the capacity of the machine. If the machine has higher capacity than needed, it may have to be run for shorter time which defeats the purpose of utilization the machine effectively. Doing other products on high-capacity machines, then setup may have to be reduced first. This way the dedicated machine would then be classified as a mixed-model.

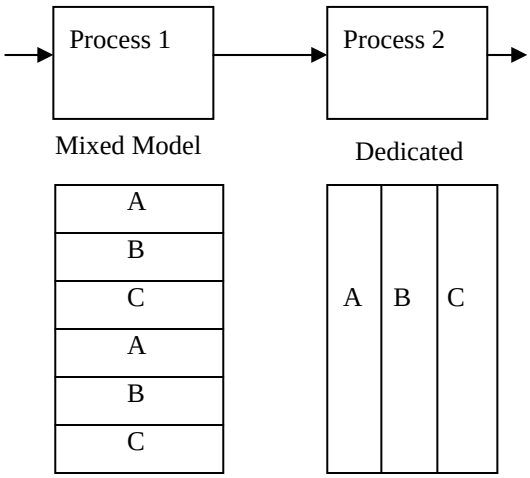


Fig. 3 Mixed-model and dedicated production

There are many tools available in lean manufacturing such as pull production, error proofing, visual management and similar approaches depending on the need of a particular situation. Experience will help determine which of these tools are most appropriate for each application.

V. WHERE TO REDUCE DEFECTS FIRST?

This is another issue that companies have difficulty in understanding - where to start the lean process.

Fig. 4 shows a two-process production sequence with each process capable of producing defects. Table 1 shows cost data of this simple production system when the defect rates of the operations are changed.

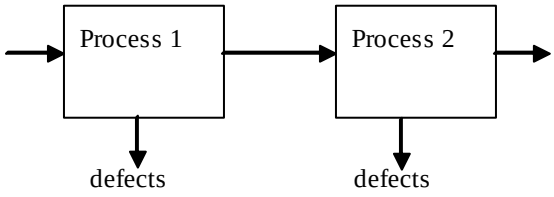


Fig. 4 A simple production system

It can be seen that the highest cost is when both processes are generating defects. The next highest cost is when process 1's defect rate is controlled. The cost is lower when the defect rate of the last process is controlled. The relative cost data is consistent irrespective of the individual values of cost taken for each process.

Table 1 COST DATA FOR 2-PROCESS SEQUENCE

Sequence	Process 1	Process 2	Cost/pc
Cost/pc	50	70	120.00
Defects %	5%	5%	129.09
Defects %	0%	5%	126.32
Defects %	5%	0%	122.63
Defects %	0%	0%	120.00

Again, looking at Fig. 5, the lean benefits of the last operation can be used by the customer, whereas the benefits achieved only in the earlier operations of a company can be accrued by even the company unless it is regulated properly.

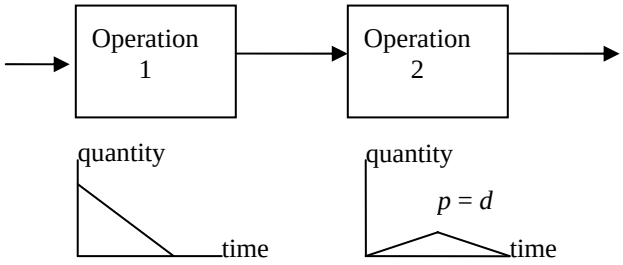


Fig. 5 Production of last operation equals customer demand rate

Thus, it is clear that if a company wants to start implementing lean approach, it is better to start from the last operation, as it will get the maximum cost savings per unit of product and also it can be incorporated into the customer's lean strategy.

VI. CONCLUSIONS

There is a misconception that lean must be implemented "from top to bottom" in order to generate meaningful results. Although company-wide implementation of lean principles is likely to produce the greatest long-term benefit, there are many significant gains to be made by identifying focused areas that will benefit from the application of lean concepts. Finding focused applications for lean principles, rather than company-wide initiatives, can help get lean manufacturing program off to a successful start.

Lean production can be clearly understood if the established inventory management principles are used to develop its principles and by adding further the concepts of waste elimination, setup reduction and lead time reduction, the companies will obtain a broader and better picture of the need for applying lean manufacturing concepts. Companies that hesitate to venture into lean manufacturing because of the vast array of tools available to use, can be motivated to take simple initial steps to get them going in the right direction.

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