LEAN MANUFACTURING ON MAKE-TO-ORDER SUPPLIERS: A CASE STUDY

Eduardo Ruiz Melchert (POLI/USP) eduardo.melchert@poli.usp.br
Marco Aurélio de Mesquita (POLI/USP) marco.mesquita@poli.usp.br
Paulino Graciano Francischini (POLI/USP) pgfranci@usp.br

Abstract
The lean manufacturing system has helped many companies to improve operational performance, mainly in the automotive and electronic supply chains. Although lean manufacturing revealed to be effective for repetitive systems, some small and medium suppliers, faced with high mix and low volume production, have had difficulty to implement the lean manufacturing. The main objective of this paper is to analyze lean manufacturing applicability to MTO companies. The results achieved from the case study conducted reveal that lean manufacturing principles, combined with a proper pull mechanism, can be appropriate to MTO, promoting better due date performance and cycle time reduction.

Keywords: Production Planning; Lean Manufacturing; Make-to-order.

1. Introduction
The rapid growth in the number of options provided by manufacturers to their customers has forced suppliers to be flexible enough to provide a large variety of customized products under high variable demand. In addition, the orders should be shipped with higher quality and shorter due-date times (SURI, 1998).

The demand for high mix and low volume orders has raised the number of suppliers operating according to the Make-to-Order (MTO) strategy. Many of these suppliers are Small and Medium-Sized Enterprises (SME) and they have to react on turbulent environments. They have to cope with unstable production schedules and materials management due to frequent changes in planned production orders, and a lot of production process inefficiencies as well. As a consequence, the Production Planning and Control (PPC) becomes rather complex and often based on inaccurate data (HENRICH et al., 2004).

Hendry (1998) point out that the big challenge for a company operating on MTO strategy is meet customer demand on time. To achieve this objective, companies have adopted continuous improvement programs to enhance their manufacturing process. New manufacturing principles such lean manufacturing (LM) have helped many companies to manufacture on MTO basis because of the reduced lead time achieved when lean was implemented (WOMACK et al., 1990).

According to Suri (1998) lean manufacturing has produced impressive results in many companies and is certainly an effective strategy but some principles such as one piece flow, takt time, level scheduling and Kanban all break down for intermittent production high mix and low volume suppliers.

Hopp and Spearman (2004) emphasize the need of a pull system to keep shop floor under control. In a pull environment, in contrast to push systems, orders are released to factory only when the total workload does not exceed a predetermined level. There are many models of such pull schemes, like Kanban, OPT, CONWIP and Workload Control System (WLC).
Besides the manufacturing efficiency, the company must make available a suitable production planning and control system in order to meet their customers needs (VOLLMANN et al., 1997). The constant meeting due dates will give to the reliable supplier a very important competitive advantage.

This paper presents a case study analysis of a medium sized cosmetics contract manufacturer, which manages different customers and high mix of products. The main objective is to analyze how lean manufacturing can be effectively implemented on MTO companies, including the PPC system requirements.

2. Theoretical Background

2.1. Lean Manufacturing

According to Shah and Ward (2003) lean manufacturing is a multidimensional approach that encompasses a wide variety of management practices, including JIT, quality systems, work team, cellular manufacturing, etc. in an integrated system. The core thrust of LM is that these practices can work synergistically to create a streamline, high quality system and produce at the pace of customer demand with no waste.

Lean Manufacturing helped bring about a change in the approach to dynamic environment, popularizing the idea of incorporating flexibility in manufacturing system without sacrificing the efficiency. The strategic approach of use buffers in human and other resources to deal with uncertainties is less attractive choice for companies operating on LM basis, thus necessitating finding ways to achieve manufacturing flexibility (ANAND & WARD, 2004).

According to Chase et al. (1998), capacity flexibility means having the ability to rapidly increase or decrease production level, or to shifty production capacity quickly from one product to another. Such flexibility is achieved through flexible plants, processes, and workers, as well as through strategies that use the capacity of other organizations. The main features of the lean manufacturing which help meet this objective include set-up reduction, multi-skilled workers, preventive maintenance, and cellular layout (SLACK et al., 1999).

According to Hopp and Spearman (2004) lean manufacturing represents a more fundamental framework for enhancing efficiency through elimination of wastes. Production is lean if it is accomplished with minimal cost. The less obvious source of cost is variability. This can take many forms, including variability in process time, delivery time, yield rates, demand rates, etc.

Hines et al. (2004) suggest that a focal point of the criticism was the ability of lean manufacturing and supply chains to cope with variability, a key aspect of lean approach. The lean pioneers came from fairly stable demand environments industries from automotive sector supply chain. High volume and repetitive demand pattern suits the application of Kanban pull-scheduling.

In many other sectors though, demand variability was a main inhibitor to lean in general, and Kanban in particular. As a result many contributors proposed agile solutions, which introduced greater emphasis on dealing with customer demand variability, flexible assemble-to-order systems, creating virtual supply chains and greater use of IT tools. (HINES et al. 2004).

Papadopoulos and Özbayrak (2005) point out that one of the major issues still needed to be tackled is unfolding the full potential of lean in other non-repetitive manufacturing environment. Therefore, future research should concentrate on extending the applicability of lean principle to intermittent (high mix and low volume) manufacturing, with a particular focus on the scheduling functions, even though its implementation may imply on some customization “of leanness was so far considered to be if not impossible then limited.”
2.2. Production Planning and Control for MTO

The PPC design is influenced by a company’s market requirements and the resultant manufacturing tasks. The technical requirements are include the manufacturing strategy, the PPC system design, and the manufacturing process itself. Developing the manufacturing strategy begin by characterizing the market targets by the company in terms of the requirements they place on manufacturing. Such requirements may include: volume and delivery flexibility, quality and low cost (VOLMANN et al., 1997).

Henrich et al. (2004) suggest that the selection of a fitting PPC concept is an important decision process and crucial for the economic success of the company. Different stages can be distinguished in the selection and implementation process, they are: a) preliminary study and evaluation; b) detailed investigation and final selection and; c) implementation.

In the preliminary study and evaluation a pre-selection between alternative PPC concepts take places. After that, a detailed investigation and final selection take place, and before implementing the chosen concept, a detailed investigation of relevant company characteristics and planning and control tasks is necessary. Also the characteristics of possible PPC software are evaluated. Finally, in the implementation stage, the PPC tasks of the shop floor have to be adapted according the chosen concept. The selected software package is parameterized and embedded into the management routine.

The Figure 2, adapted from Vollmann et al. (1997), summarizes the above concepts and helps the hierarchical PPC system designing.

![Figure 2 – PPC system design](image)

Stevenson and Hendry (2005) suggest that the typical function of a PPC system include planning material requirements, input and output control (I/OC), and the scheduling and sequencing of jobs. According to Soman et al (2004), for those companies that operate on MTO strategy, the production planning focus is on order execution and the performance measures are order focused e.g. due-date performance, average cycle time and number of late jobs. The main competitive advantage is shorter delivery lead-time. Capacity planning, order acceptance/rejection, and attaining high due date adherence are the main operations issues.

Stevenson et al. (2005) proposed the following criteria to evaluate the applicability of alternative PPC system in the MTO sector:

a) inclusion of the Customer Enquiry Stage for delivery date quotation and capacity planning;

b) inclusion of a Job Entry and Job Release stages, focusing on due date adherence;
c) ability to cope with non-repetitive production i.e. highly customized products;
d) ability to provide planning and control when shop floor routings are variable;
e) applicability to Small and Medium sized Enterprises.

Stevenson et al (2005) conducted a study comparing many PPC systems and their applicability to the MTO industry. This study included systems like Kanban, CONWIP, POLCA, TOC and Workload Control (WLC). The result suggested that WLC is the system that better cope with the most characteristics and requirements of the MTO environment.

2.3. Workload Control Model

Workload Control is a PPC concept design for complex production environments, such as the job shop and MTO industry, and originated from the concept of input-output control (I/OC). In general terms, the input of work to the shop floor is controlled in accordance with the capacity of work centers (the output rates) through the use of a pre-shop pool and job release mechanism (STEVSON, 2006).

Haskose et al (2004) point out that WLC put emphasis on control and attempts to manage the average lead times to match pre-determined norms. It does this by having a good order acceptance and release policy and planning future capacity to match the arrival orders and the workloads they impose on the work centers. It should be pointed out that most commonly used production planning software, simple sequencing and scheduling system, MRP or OPT all assume fixed lead time planning values, independent of the workload at any time.

The Figure 3 summarizes the hierarchical control framework, indicating the key production stages to control.

![Hierarchical backlog control framework](source: Stevenson, 2006)

2.3.1. Customer Enquiry Stage

The enquiry may come with a fixed delivery date and merely ask for price. In this case the first step is to check whether this can be achieved. Taking the specified delivery date, backwards scheduling through the work center needed gives the latest release date the job has to leave the pool. If the enquiry requests both a delivery date and a price to be quoted, then the first step is to calculate possible alternatives delivery dates (KINGSMAN, 2000). The decisions made in this stage use the expected pool delay and queuing times at shop floor resources to estimated the delivery lead time as only rough cut planning is required until an order is confirmed (STEVSON, 2006).

2.3.2. Job Entry Stage

If the customer accepts the tender, the company can start to plan production, finalizing processing requirements, including job routing, and the necessary materials. More detailed
planning for the workload of the job and the capacity of the machines it will visit can also take a place (STEVENSON AND HENDRY, 2005). Customer enquiry management can help to provide a suitable mix of jobs for the job entry stage. Job entry for some jobs may be immediately after the customer enquiry stage; while for others it may be some weeks later. Therefore, if the customer accepts the quotation, it is necessary to re-evaluate the delivery date, it ensure that the company can still achieve this (STEVENSON, 2006).

2.3.3. Job Release Stage

Finally in this stage the company must decide when a job is to be released onto the shop floor and start of production is to be signaled. Once release the job can be considered as WIP. The priority dispatching is related to the way jobs are sequenced at machines on the shop floor such according to a simple FIFO policy (STEVENSON & HENDRY, 2005). The job release stage provides additional shop floor control through the release backlog of individual shop floor resources and the shop as a whole (STEVENSON, 2006).

2.3.4. Capacity management

A change to the capacity resources has an impact throughout the hierarchy of backlogs, influencing the total, planned and released backlog lengths. Three main options to manipulate the output rate are: a) worker can be reallocated from an under-loaded to overloaded resource; b) overtime can be assigned to one or several resources and; c) the user can subcontract part or the whole of job (STEVENSON, 2006). All the work in the company in any stage for each work center gives the total workload of work the company has to process. The time required processing all this work, plus the processing times for the new enquiry thus become the delivery time that will be required for a new enquiry made at the current time, if it is processed normally without any priority and without any changes to the capacities currently planned for future periods (KINGSMAN, 2000).

3. Case Study

3.1. The Company

The case company is a medium sized enterprise, currently employing 200 people and operating as a contracted manufacturer in a cosmetics supply chain. The customers of the company are ranges from small to large companies of the sector. The company manages around 2600 SKU’s, each one with a different product and packaging characteristics. The shop floor of the company consisted of 17 filling lines designed for a particular job and workers are specialized, making it difficult ensures the efficient utilization of the productive resource.

The redesign of the production system was motivated by the difficult of quoting and meeting customers’ due date, low operational efficiency, and frequent customers complaints. The market requirement was focused basically in three points: low cost, delivery date adherence and capacity flexibility. The last two features are considered essential for two of the major company’s customer in which operated with highly variable demand.

The manufacturing process consisted of filling lines designed to work with high volumes, workers specialized, high set-up times, and complex machines that usually broke down causing low operational efficiency and lack of flexibility. PPC system consisted basically of a material requirement planning (MRP) software. There wasn’t any formal procedure to detail sequence production orders and the priority many times was defined according to customer’s pressure. As a consequence, the company faced great difficulties to quote and meet the due dates, due to a poor production control and capacity management.
3.2. Manufacturing strategy

The first step was revising its manufacturing strategy, which resulted in formulating two main goals: reduce delivery lead time and reduce operational cost. The new manufacturing strategy becomes important to assure that manufacturing capabilities were developed to support its competitive advantage. A clear statement enabled managers recognize the changes that could be required in design both manufacturing process and PPC system.

3.3. The Lean Manufacturing implementation

The manufacturing process was redesigned based on lean manufacturing principles. LM system was implemented following the main steps as related in the lean literature. First step adopted was changes in company culture and get people commitment for sustaining the change toward lean. After that, process flow, work method and production times were revised.

The main issues faced by the managers were simplifying the shop floor, developing multi-skilled workers and set-up reduction. Filling lines became more flexible which could work with a large variety of product in small quantities. It was possible by changing the complex machines for simple and small machines. The simplicity of machines and changes made in the set-up procedure helped to reduce significantly the set-up time. Workers were trained to handle multiples products bringing more flexibility for the shop floor. A productive maintenance program took place aiming to guarantee higher process reliability. The achievements have been made after implementing lean tools according the set plan includes: plant efficiency improvement, setup time and delivery lead time reduction.

3.4. PPC system design

The design of the PPC system, as suggest by Henrich et al. (2004) was initiated with a preliminary study and evaluation of the alternative PPC concepts. Although many lean tools have been implemented successfully its PPC concepts couldn’t cope with that complex production environment. Analyzing the relevant company characteristics it was evidenced the need of a job release module that was capable to manage the job sequencing at machines on the shop floor. Also it should be possible to evaluate the capacity of all resource involved, worker and machine aiming to facilitate the decision process. The company opted for a customization of its MRP system which included the design of two modules based on the WLC concept.

The job release support module, Figure 4, was designed to help the user to scheduling and sequencing the jobs. The number of workers allocated is monitored hour by hour which permits to identify under-load and overload resources. Once workers are multi-skilled, the foreman can look ahead to the requirements of imminent jobs and reallocate workers to specific filling lines, thus increasing its output rate. The module also highlights the capacity and efficiency rates.
A second module implemented was the customer enquiry management, Figure 5, that allowed estimate the delivery date using the expected pool delay and queuing time at shop floor resources. The module provides to the user the total backlog for each filling line and it is visual aid to negotiate the delivery date with the customer. If the customer requires a shorter delivery date the user can consult the job release module and negotiate with the foreman the possibility of change the capacity constraint resource on the appropriated dates, thus increasing the total daily capacity and reducing the total backlog.

3.5. Current situation

The overall implementation has covered many issues described by the published literature. Stating a clear manufacturing task the company was capable to redesign its manufacturing process and select an appropriated PPC system. The successful PPC implementation improved customer relations with the company. The availability of online information systems resulted in faster decision-making. The worker satisfaction level had increased efficiency in work process and reduced overtime. The main results achieved by the company are showed below.

<table>
<thead>
<tr>
<th>Key Performance Indicator</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average delivery lead time (days)</td>
<td>25</td>
<td>12</td>
</tr>
</tbody>
</table>
In spite of the fact that company has achieved an outstanding performance in its operations some issues still remain to be improved. Due to the delivery lead time reduction many suppliers are facing difficulties in meeting delivery schedule. Future actions require the use of web technology in order to extend the advantages of WLC through the supply chain.

4. Conclusions

The case study highlighted a number of factors influencing the development and implementation of a PPC model for a lean manufacturing and MTO company. Achieving high flexible manufacturing to cope with variability is the big challenge faced by MTO suppliers. Lean manufacturing principles such as multi-skilled workers, set-up reduction, simple and small machines help many companies reaching its goal. It was evidenced that some lean principles including level scheduling, takt time and Kanban couldn’t be applied to the environment that requires high variety of product, low quantity and variable demand. The WLC concept is based on three main stages: customer enquiry, job entry and job release demonstrated to be an effective system to cope with these characteristics. Lean principles combined with an appropriated PPC system give manufacturing an important competitive advantage.

References


