An Empirical Use of Lean Management Methods to Aid Design and Development Planning for ETO

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ABSTRACT

Engineer to Order (ETO) businesses have to face the task of handling high customer requirements complexity and, ultimately, coordinating all activities to respond to customer requests efficiently and effectively. Planning the activities of the design, manufacturing and assembly departments in these contexts is a dynamic activity, even considering the uncertainty of lead times and the difficulties in estimating the workload of resources. Literature has concentrated mainly on preparing methods for uniform make to stock environments, often ignoring the needs of ETO companies. Interestingly, while historically lean management techniques have been developed and applied to mass manufacturing, empirical evidence suggests that they can also be implemented effectively in ETO firms. This paper aims to present a framework to help design, manufacture and assembly preparation in the sense of an ETO. The approach blends project planning criteria with lean management instruments, i.e. Asaichi, and tools for visual communication and management. This has been successfully implemented in an organization demonstrating the ability to improve planning efficiency, consistency in the business and, eventually, execution results.

Keywords
Design planning, Engineer-To-Order, Lean manufacturing, Lean management, Production planning.

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Introduction

An Engineer to Order (ETO) supply chain is a supply chain where the decoupling point is located at the design stage, thus the production and manufacture of' one of a kind goods falls into this category. ETO companies are increasingly needed nowadays to reduce lead times and costs, thus offering high levels of versatility and flexibility. Because ETO companies work in a dynamic and unpredictable setting, it is a major challenge for them to handle this trade-off. A well-managed Production Planning and Control (PPC) process can help companies be responsive to customer satisfaction while maintaining a high level of productivity.
The different steps should be properly integrated to ensure the PPC process is efficient and reliable. In the Make to Stock setting PPC manages capacitated systems effectively as multi-item single-machine systems. Stevenson et. al. reviewed the PPC literature in Make to Order context, demonstrating how to apply the various methodologies and the differences in the literature[1], [2].
Under the term "lean management", an important collection of methodologies and methods that can support PPC processes Anecdotal evidence suggests that combining lean management with other methodologies that are used in the PPC framework contributes to performance enhancement. For example, to enhance efficiency of Material Requirements Planning (MRP) in high-uncertainty situations, to align MRP with lean development programmes. Based on a study of 382 multinational manufacturing firms, they found that operating performance increases dramatically when lean development projects help MRP systems when high rates of demand fluctuation are at stake.
Notwithstanding their significance, literature has seldom considered the needs of the ETO industry in operations and supply chain management. Nevertheless, researchers have concentrated far less on how to manage processes and schedule development plans in ETO companies than in MTS environments with high volume. Literature provides especially few reference models for PPC in ETO. Interestingly, while historically lean management techniques have been developed and applied to mass manufacturing, empirical evidence suggests that they can also be implemented effectively in ETO firms.
This paper seeks to address these gaps in the literature by adding to the debate on the PPC cycle in the ETO sector, taking into account the potential for lean management methods in performance improvement [3]–[5]. The goal of this paper is therefore to provide response to the following research question: "How to incorporate PPC process phases in an ETO company that leverages lean management tools? "We are suggesting a technique for this reason and analysing the effects of applying it to a case study in the ETO industry.

Background

PPC in ETO industry:

Various process models of PPC in ETO have been presented in literature. Little et al. claim that also in ETO context integration of planning and execution is pivotal for ETO manufacturers to be effective. They propose an integrated planning approach, aimed at developing three plans, namely design, production and assembly plan. These are developed considering concurrently current loads and capacity of the design, assembly and factory.

Little et. al. validate a planning and scheduling reference framework for ETO companies by empirically investigating the phases that are performed by a set of companies. In particular, Little et. al. proposes the following phases: (i) Product configuration, i.e. development of the detailed specifications of the product in agreement with the customer; (ii) Master production scheduling, i.e. the schedule of the product building; (iii) Design planning, i.e. planning of design activities considering capacity constraints;
(iv) Project requirements planning, i.e. each new order is considered as a project, and the planning is meant to define the completion date of the order given the orders already present and capacity constraints; (v) Shop-floor scheduling,
i.e. scheduling of production of parts and sub-assemblies; (vi) Assembly scheduling, i.e. the schedule of the final assembly.
Chen underlines the importance of the interaction among sales, production, and engineering operations to develop a concurrent PPC process in ETO contexts. The sales, production and engineering departments are involved to develop costs and lead time analysis of the product. Master production schedule is performed, activating the design of product specification, which are input for the material requirements planning and the capacity requirements planning. Then, an iterative bidding process is performed with the customer, to refine and improve the planning (hierarchical planning) and the scheduling (incremental scheduling) by modifying product specifications and work contents based on customer and sales department requirements, with a number of iterations dependent on the complexity of the order [4], [6]–[8].
Among the few others, Adrodegari et. al. develop a process reference framework for machinery-building industries. They show the flow of phases to be performed from the request for proposal to the final cost assessment upon order completion. They divide the framework in two phases, namely Engineering and Plan, and Execution and Control. The first phase is intended to get the first contact with the customer to gather her/his needs, then to design the product, and, finally, to develop plans for satisfying the customer. The second phase, i.e. Execution and Control, encompasses the actual production and assembly activities.
Lean management tools:
Lean management is a production strategy, known also as Toyota Production System (TPS), developed in Japan by Taichi Ohno in 1950s. Lean management helps in reaching operational excellence, eliminating wastes through continuous improvement and standardization, building a solid foundation to change and a culture oriented to use workers not only physically but also intellectually. Various are the tools that are effectively used to eliminate wastes in the organization: kaizen, just-in-time (JIT), value stream mapping (VSM), kanban, 5s, etc.
Lean management tools were firstly designed and applied in automotive industry, then their use spread over to other sectors. Evidences support that companies belonging to the ETO industry can successfully apply them as well. For instance, Slomp et al. tested the applicability of lean production in a high variety/low volume context and measure the improvement in terms of on time delivery [9]–[11]. They observed an improvement from 55% to 80%. Birkie et. al. performed two in depth case studies in capital goods manufacturing companies. They observed that implementing lean management practices allows to achieve performance improvements in the shop floor under high uncertainty

Methodology

The methodology built in this study aimed to help the ETO PPC cycle by applying lean management strategies to minimize volatility and address the high context uncertainty. We are especially interested in the PPC phases that relate to the medium-short term and consider the steps required to schedule the design and development activities.
The methodology presented here is based on the literature and consists of a two-step approach in which ETO preparation and lean management strategies are combined and implemented after a particular customer order has been issued. The two phases are as follows: (i) Project requirements planning: specify the activities to be carried out for each new order (including the design) and determine the estimated lead times; then include the starting and ending dates for each of them; (ii) Project scheduling activities taking into account capacity constraints and work in progress: based on the starting and ending dates identified in the pre-arrangement.

Project requirement planning:

Figure 1 provides an example of the activities conducted in phase 1: when a new customer order N arrives, the customer specifications are identified and the anticipated due date is set. The tasks to be carried out and their complexity levels can be defined and the average estimated lead time involved, depending on the particular customer requirements. Then, based on a backward calculation, the dates are specified, in order to respect the delivery lead time, when and operation for making order N will start and finish.

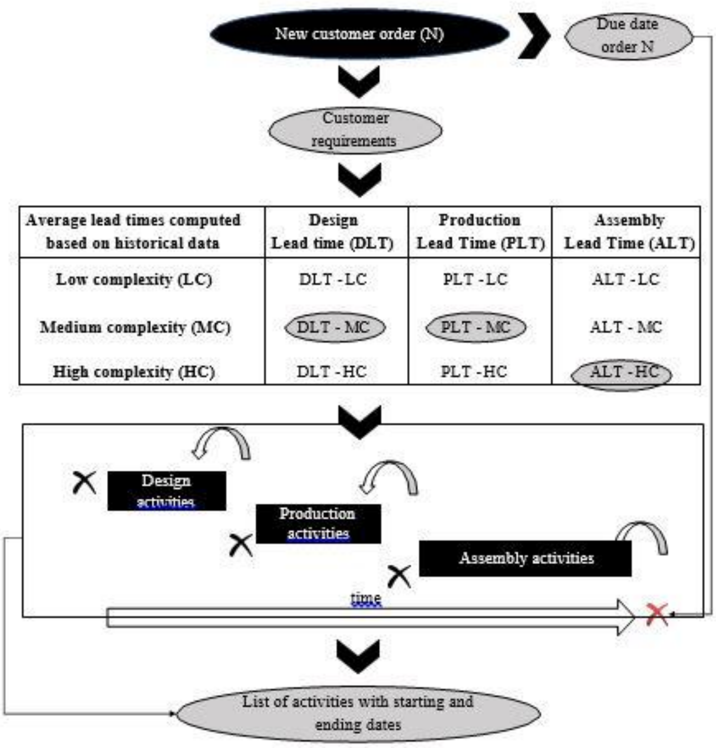

Figure 1. Project Requirement Planning

When the order arrives, it is considered as a new project to start, characterized by different activities to be performed, including the design, production, and assembly. The information provided by the customer, about its needs and specific requirements, allows the company to define the expected lead times to engineer, manufacture, and assembly the product. The lead times are calculated based on average values using historical data. They are related to the length of the activities in three different conditions, named: high, medium, and low complexity.

The complexity is associated to different product characteristics, which vary on the departments. In the engineering department, the lead time depends on the complexity of the product design, and ranges from (i) low i.e. if the new product design has many commonalities with existing designs engineered for previous orders, to (ii) high i.e. if the innovativeness with respect to previous designs is high and it is engineered completely from scratch; while (iii) medium refers to the case when there is an average situation among the two-previous described.

In the production department, the lead time depends on the complexity of the production processes of the components, and ranges from (i) low, i.e. if the components can be realized easily with only one machine/line setup, and basic machine tools/workforce movements, to (ii) high, i.e. if the number of machines/lines setups is high, and the machine tools/workforce movements are complex; while (iii) medium refers to the case when there is an average situation among the two-previous described. In the assembly department, the lead time depends on the complexity of the components/subassemblies handling activities, and ranges from (i) low, i.e. if the weight of the components/subassemblies is low and the maneuverability is high, to (ii) high, i.e. if the weight is high and the maneuverability low; while (iii) medium refers to the case when there is an average situation among the two-previous described.

Once defined the complexity of the different activities to be performed, the expected lead times can be associated. Then, together with the due date required by customer, they are used to compute the starting date needed to achieve the delivery performance required. The output is the list of the activities needed for every order to be completed, and the starting and ending dates computed for each activity.

The Case Study

The methodology developed was applied to a real ETO industrial context, where the researchers have conducted a consultancy project. The researchers signed a non-disclosure contract, so the name of the company and the exact data cannot be shared due to privacy reasons. Therefore, the company will be called hereafter “ABC” and the methodology will be described without in-depth numerical examples.

ABC is a manufacturing company, which designs and produces electric equipment for the energy industry. All the products are made using an ETO approach, with a completely tailored design. This increases the variety, together with the uncertainty and complexity of the design and production processes. Therefore, the company struggles in defining a priori the level of customization required by the customer, which can strongly change from one order to the other. Thus, the possibility to plan activities by forecast is unlikely. The design activities are performed to order and strongly affect the production ones. The bill of material (BOM) is not ready until the new design is completed, and the engineering lead times are variable based on the design complexity (e.g. the level of innovativeness with respect to the previous designs, the technological novelty). This makes difficult to anticipate production and have materials kept in stock when the order arrives. Moreover, the machines set-up and cycle times strictly depend on the specific product design (e.g. the product shape and dimension).

For these reasons, the company managed the orders without applying a capacity planning: the actual status of the activities and the potential resources overloads were hard to be forecasted. The main focus was in finishing as fast as possible the activities required per each customer’s demand, following a sequential arrival order. In doing this, the interaction among departments was low as the visibility of the actual status of each order. The company was struggling in assuring the expected delivery lead times, with low delivery performance (on time delivery was between 30 and 40%). Therefore, the need of ABC was to improve the responsiveness of the design and production processes, handling this elevated uncertainty and assuring better delivery performance, while keeping high flexibility and customization. To achieve this aim, the researchers proposed to the company the methodology described above, based on planning activities to order, reacting fast to changes by exploiting lean management techniques. The methodology applied was able to improve the company’s delivery performance (i.e. on time delivery) of 60% more (in terms of number of pieces delivered on time to the total number of pieces delivered ratio). In the following, the application to company ABC is defined and discussed in its different steps.

The methodology was developed, tested and assessed in six months in one of the company's plants.

To perform the project requirement planning, the main department involved was the planning office, supported by the researchers. The activities consisted in analyzing the historical data related to previous orders and identifying associations between the order characteristics and the average lead time needed to fulfil it in the different processes (engineering, production, and assembly). Then, for each new order, the complexity is defined based on the main commonalities of the order with these characteristics. The outcome was a "configurator of complexity" that allows the company to define the lead times based on specific levels of complexity. Moreover, a tool was developed in excel through a VBA macro to compute the delivery performance required. One employee of the planning office was partially dedicated to this activity, generating, at the beginning of the project, a certain level of scepticism from the office. In this case, the ability of the researchers in supporting the phases of development was very important to explain clearly the reasons why this step is so important. Also, once developed the tool, the benefits were instantly perceived by the entire office, thanks to the easier and faster communication of reliable delivery lead times to the customer. The run of the macro occurred two times per day. The main output was the list of activities to be performed and the lead times required to perform them.

The activities scheduling phase was conducted by a team composed by the production departments' managers, the logistic manager, and the plant manager, supported by the researchers. Three days a week the Asaichi meeting was performed, because the chosen time bucket, given the processes characteristics, was equal to two days. The A3 paper, together with other techniques were applied in the assembly department, the main bottleneck of the process (i.e. the activities cannot start without all the components/subassemblies ready). In this department, the main causes of delays and time wastes were related to the lack of materials and resources needed for the activities. For this reason, these needs were made visible and intuitively recognisable by means of a re-layout project (from straight line to U-shape layout) and the definition of the kitting area. The U-shape layout optimises the assembly flows reducing movements and walking. The main benefit, from a planning point of view, is that it improves the visibility of the workstations and makes easy to see the current status of the activities, identifying as soon as possible eventual problems. The overload of production resources was also solved faster. In the as-is scenario the delays could not be managed: if the resource was oversaturated the following activities must wait given the complexity to manage the outsourcing decision too late in the process, even if the production capacity of the other plants of the company could be used. While, after the application of the methodology, the decisions related to outsourcing the activities to the other production plants based on their available capacity was made on time and quick. The kitting area creates an ad-hoc location where to create the "assembly kits" (i.e. the group of components and subassemblies needed to perform activities), which reduces handling and non-value-added activities in the assembly department. The main benefit, from a planning point of view, is that, passing next to this area, is very intuitive for the assembly department manager or its employees to understand the materials current status.

Conclusion

The study began from a realistic and real industrial challenge that is typical of the ETO realities: the complexity of handling high uncertainty and therefore coordinating all activities to fulfill customer orders effectively. The emphasis is on planning and controlling the design and manufacturing activities which rely on the level of customization and complexity of the single customer order. The conventional approaches to planning have been found to be not successful in this context. First of all, the number of activities to be conducted to order, including engineering, manufacturing, and assembly, is higher than average.

Furthermore, given the high variability of the operations, the capacity of each department can not easily be established a priori. For this purpose, the study suggests a methodology starting from the preparation of a project requirement, specifying the starting date to be followed for each order based on the delivery lead time needed by the client, and then applying lean management methods to coordinate the tasks effectively and maintain the timing. The Asaichi Morning Meetings and the Visual Management methods in particular allow the organization to recognise challenges as they arise, and to follow a problem-solving approach based on a continuous philosophy of change. The frequent contact between departments makes it possible to respond to the changes, cope with the potential pressure, correctly manage the workloads and take into account the particular characteristics of each customer order and the departments ' actual status.

The suggested approach was applied to a particular case study. Results demonstrate the efficacy of lean manufacturing in promoting preparation initiatives in highly dynamic and unpredictable environments, maximizing available capital, minimizing non-value-added initiatives and increasing efficiency. Nevertheless, the authors are aware that a single case study is not adequate, even if it is well representative of the context presented and promising in terms of outcomes, to generalize the results obtained to the entire ETO context. But, the technique was explained in depth, making it possible for other researchers to test and verify it in various contexts, with consequently high reliability. Therefore, the extension of the method to other industries and its improvement is suggested as further work in order to address this limitation and improve the generalizability of the technique.

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