Centralized vs Decentralized Production Planning in ETO Environments: A Theoretical Discussion

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Abstract. The characteristics of ETO production call for further analysis to investigate the implications of traditional (deterministic) systems of planning i.e., centralized, and hierarchal, compared with decentralized systems. Accordingly, this study delineates the potential implications of centralized and decentralized planning approaches in the context of ETO. Hence, the contradictory pressure for either decentralized or centralized approaches promote one-sided solutions accentuating the crucial significance of a theoretical discussion. Our analysis suggests that implementing decentralized systems should engender flexibility, transparency and responsive, which in turn can strengthen the impact of production planning on project delivery. In contrast, implementing centralized systems is likely to stifle the impact of production planning due to the rigidity, sequential interdependence, and the top-down nature of this approach. As such, our study provides opportunities for extending extant theory on centralized and decentralized production planning within ETO contexts, while providing a tentative framework for ETO practitioners that can be applicable when decisions concerning an (re)evaluation of production planning systems are to be made.

Keywords: Engineer- to-Order; Centralized production planning, Decentralized production planning

1 Introduction

The productivity of Engineer-to-Order (ETO) production can be improved by the restructuring of both the production process and production management. A vital point in the required development of such a restructuring lies within the area of production planning. With regards to production planning this restructuring should not merely focus on the planning and control activities and resources of manufacturing and assembly, but it should also take into account the planning requirements of activities in the fields of procurement, quality control, engineering and production, production facilities and plants involvement. This is because ETO is characterized by the strong influence of customer specification and by the continuous changes to the specification during the project; from design and engineering to time of delivery [1].

The large volume of engineering requires an equivalent effort by the ETO manufacturer and thus, also to their need for high production flexibility to handle unpredictability. Compared to traditional (serial) production, in ETO all production activities required for design and production must be synchronized, especially with respect to delivery time, something that indicates that many of the engineering and production processes needs to be executed in parallel. Hence, due to such complexities the planning of production can be affected by a disintegration from the overarching plan leading to problems of incomplete information sharing along different stages in the production. Such issues are probably more evident when operating with several production plants [2,3]. This is because a multiple-plant context operates with a higher level of intra-and interorganizational interactions compared with a single plant (e.g., standalone business unit), and therefore exposed for more disturbance. Hence, a major difficulty in managing ETO is to integrate planning of different stages or production processes within a multiple project environment. Consequently, the characteristics of ETO production implies that there is a need for further emphasize to whether one should embrace and improve the traditional (deterministic) approach of planning i.e., centralized, and hierarchal systems, or if ETO firms operating with several production plants benefits from collaborative planning approaches, i.e., decentralized systems. Accordingly, there seem to be an inherent conflict in these two areas of production planning systems, which warrants further discussions – which this study aims to contribute with.

The rest of the composition of the study is as follows: An introduction to relevant centralized and decentralized production planning systems is provided in chapter 2, while chapter 3 conceptualize the ETO environment within the realm of those systems. In chapter 4, we provide a discussion which also represent the frame of reference for the concluding remarks in chapter 5.

2 Theoretical background

2.1 Centralized vs decentralized production planning

The tendencies in production planning can take different forms. At one extreme, production planning is almost exclusively centralized. That is, production is seen as a linear and predictable entity that can be planned by a central authority and then precisely implemented [4, p. 256]. Here the production plan follows a predetermined approach, where the demand planning for e.g., the next quarter is established only by one central level without involvement of others. As such, decision making (head/master planner) is often disconnected from where the production or service take place. It follows a superior-subordinate management philosophy where control decisions propagate in a top-down manner and the status is reported from a bottom-up fashion. At the other end of the spectrum, the production planning system is almost completely decentralized. Here each plant is operating as a stand-alone business, deploying a production planning approach for 'local' optimization. Compared to the centralized approach, the production plan is perceived as a resource for situated action where the involved actors can adapt plans to requirements of its enquiries. As such, neither the production nor the planning activity is adhered to as something predictable [5]. Consequently, decentralized production systems require control and autonomy to be distributed to more than one decision maker or level, to be able to react to local conditions in real time. As such, a decentralized production planning system is based on autonomous entities with enough decision space as its core.

Hence, production planning is a key mechanism in manufacturing, since planning puts the firm in a position to meet the production requirements as effectively as possible [6]. Supported by digitalized planning systems and solutions it can mitigate uncertainty by providing information for better decision-making [7]. For instance, in central production planning systems, such as MRP II (Manufacturing Resource Planning), every decision concerning all facilities is made at one central level, distant from other production plants. Likewise, ERP (Enterprise Resource Planning) which is a centralized software composed of a set of applications to manage vital functions of a firm (e.g., sales, inventory and planning). The strength of such systems is their power to integrate information in a streamlined manner which can ease the information flow enterprise wide. Hence, it helps in increasing transparency in workflows leading to better forecasting, as delivery dates can be planned in advanced to meet customer needs. As such, a centralized approach provides opportunities to create a big-picture information flow and consistency, overall risk management and coordination [4]. Especially, in contexts where work operations can be conducted independently and low levels of co-operation between plants is necessary. Other benefits with centralized planning systems when operating with multiple plants (that produce the same or rather similar projects) is that it allows for economies of scale for other firm functions such as procurement. However, in changeable environments with high variation in e.g., engineering and production, the applicability of centralized planning systems decreases. The same can be argued if the production processes are complex and interdependent; operating with multistage procedures that causes production processes to start and finalize at different plants. Thus, this type of system appears suitable particularly for firms operating in environments with high determinism [8]. As a result, scholars focusing on complex production environments [e.g., 9,10] have started to question the effectiveness of centralized production planning systems and thus shifted their focus towards more decentralized modes.

A decentralized system is claimed to be a key element in effective project and production management and is predominantly focusing on the social sides of the production planning processes in addition to technical results [4]. Decentralized systems are dynamic in nature and demonstrate a high level of adaptability to changes in production and are known to ease communication, increase flexibility and autonomy. Decentralization is hard though; one must be cautious so that it does not get too detached and hampers the overall goal. If not managed, it can result in unsystematized production with informal decentralized management and dependency of tacit knowledge [11]. Thus, to succeed, the production planning system must become more collaborative [12]. Collaborative planning is based on information exchange in support of joint strategic, tactical and operational planning, forecasting and demand fulfilment process [13, p. 74]. In complex project environments a frequently applied system supporting collaboration is the Last Planner System (LPS; a lean production approach) [14]. Here, manufacturers are operating with a close integration mode, where employees are part of the decision-making process, while the head planner/headquarter act as a facilitator more than as an authority [4].

LPS composes three levels. First, at an overarching level, where long-term planning goals are set. It is here one decides what aspects that need to be achieved during the execution of the project [14]. Secondly, at a medium-term planning level where obstacles are identified and detached, ensuring that the necessary resources, e.g., materials, information, and equipment, are made available. Thirdly, at the short-term planning level, the focus is turned towards production reliability and timely availability of needed resources. Thus, effort is put on shielding planned work from upstream variation and by encouraging and initiating conscious and reliable commitment of workers [14]. As such, an integrated approach is developed to support the decentralization of decisions to lower levels of operational responsibilities. In so doing, it enables for planning and control activities to not only start according to predetermined time schedules, but also accommodate for planning according to unforeseen events. For instance, when changes in customer orders or engineering changes occur after the production has started LPS enables a proactive approach to handle uncertainties [15]. This is because other levels than just the central decision-making level can exchange information on conditions in their own executions concurrently. As such, required information is more accurate because it is subjugated by the actual customer order and/or engineering changes. Hence, this helps bypassing the inability to secure delivery times as one manages to handle deviations from the original production plan in a collaborative manner. Accordingly, decentralized planning is more agile and responsive as it eases re-optimization which is hard to achieve in centralized production planning. Similar argumentation can be valid when considering variability and disturbances within the context of multiple-plants and production planning. For instance, if manufacturers are confronted with a high degree of complexity and uncertainties, autonomy should be assigned across plants in order to increase responsiveness and flexibility in the production [2, 5]. More so, when engineering and production is conducted at multiple plants, it is difficult to determine what and how much work will be available at a future state. It makes it a hurdle to arrange for specific resources requires, and thus it is impractical to develop predetermined and rigid plans [14] especially since it has a negative effect on the overall decision space (e.g., which adjustments can be accepted at which level and at which consequences).

As can be seen the most important differences between them seem to be the robustness in systems. In the following section, we conceptualize whether the characteristics of ETO and its environment fits with a production planning system following a centralized planning approach, adhering to a fully decentralized approach or benefit from a collaborative mode of organization.

3 Conceptualization

As stated earlier, ETO is characterized by an inherent uncertainty in product complexities and high levels of customer involvement, and hence interdependencies between plant functions and activities [16]. The aspects of interdependencies require extensive cross-functional integration [17] which induce additional complexity in planning processes and tools [16]. As such, it is important that ETO firms deploy a suitable planning approach that accommodates the embedded complexity in their environment [6]. Especially, since a lack of fit between the characteristics of the environment and the chosen planning approach can impose negative effects to the performance outcome [9]. This notion is particularly important to accentuate for ETO firms compared to e.g., Make-to-Stock (MTS). This is because the latter manufacturers often operate in an environment characterized with higher levels of predictabilities which reduce potential obstacles in planning and control issues and thus favors the universalistic 'one size fits all' planning approach [10]. Despite this being heightened, existing planning approaches applied to ETO are mostly based on a serial production type of thinking [18] which adheres to a 'linearism' way of thinking. A linear strategy implies dependent and sequential phases executed according to a plan established in the beginning of a project [19]. Hence, it does not accommodate the uncertainties that can be found in change operations regarding for instance, engineering after the entry of customer enquires [16] which are common, if not constant in ETO. For example, in MTS environments, engineering changes are actions that are planned priori production start (except for changes owing to safety issues). In this context, changes are implemented in the next product version or production run; updated design and engineering drawings are made, the inventories are gradually phased out, and new parts and components are ordered from suppliers [20, p. 2]. While in ETO, engineering changes must be instantly implemented and cannot be postponed until a new/next product version or production run, causing work in process being disposed and parts and components to be reworked or even scrapped. As such, the embedded variabilities in engineering work can have a huge impact on everything from ongoing production, assembly processes and inventory, leading to the need of immediate replanning [20].

More so, the obstacles regarding uncertainties accentuated with regards to linearism are similar to those aired in centralized production planning systems, such as MRP II and ERP which are dominating the current practice [4]. Despite their dominance both ERP and MRP II have been argued to lack an appropriate level of flexibility and responsiveness. For instance, it is rather challenging to accommodate changes in MRP II in ETO firms, as more often than not, the system relies on a predefined bill-of-materials (BOM) structure, which is not easily changed between projects [18]. Besides, the changes in BOMs are often made in engineering through an iterative process between customers, procurement and sometimes also suppliers, which reinforces the difficulties in changing predefined production plans. Furthermore, it is important to acknowledge the premises of MRP (II) systems, as they are based on two erratic assumptions. The first being the infinite capacity levels of production lines, and the second is based on constant lead-times [8]. While the former can create obstacles when capacity levels are reaching its limits, the latter is challenging when practicing with fixed values. With fixed values one tends to apply long lead-times in order to cope with uncertainty, which induces additional inventories [8]. Hence, in ETO this is problematic as one only operates with variabilities. Consequently, the changeable environment and variation in design and production in ETO environments may severely affect the applicability of such centralized systems [4]. Adding to this, are the issues of coordination in planning when operating with multiple production plants. Often, there is quite a bit of room for autonomy and local decision making for planners in their work, where the decision space depends in part on the amount of variability in orders and processes and on the knowledge and experiences of the planner. However, when operating with multiple production plants this can become a hurdle process [12]. Herein lies the vital differences in management characteristics, i.e., the degree of autonomy or decision space the plant/headquarter management has concerning different decisions such as capacity, facilities, organization, quality systems and hence, production planning and control systems [2, 3]. Thus, manufacturers that are encountered with a high level of complexity and uncertainties either due to e.g., internal miscalculations such as lack of capacities or due to external circumstances in e.g., change orders, should operate with autonomy among its plants in order to ease such unforeseen obstacles [5]. This does not mean that a full decentralized approach is the most appropriate one to adhere to. ETO firms can still accommodate some of these complexities and uncertainties through centralized determined software's, however, to achieve this, one requires some level of coordination at least. Thus, a suitable production planning approach is one that operates in an integrated manner in parallel with a e.g., ERP system as the main coordinator of the different planning processes among and between plants. According to [21] any mode of production planning and control holds elements of both centralized and decentralized features. Consequently, a planning system which assigns authority in the decision space primary on a centralized level is preferable only if the level of uncertainty and complexity of its production system is low [5], which hence does not fit within the context of an ETO environment.

The below framework (Figure 1) depicts the implications of deploying centralized vs decentralized production planning within the context of ETO and multiple production plants.

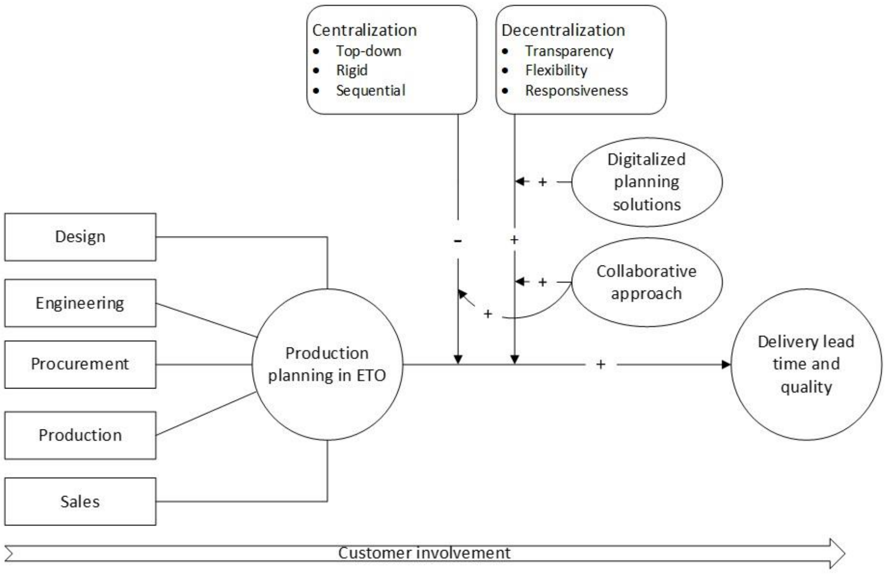

Figure 1. Impact of centralized vs decentralized production planning in the context of ETO*
*Notes: (+) indicates positive/strengthening impact; (-) indicates negative impact on project delivery

As shown in Figure 1, considering the characteristics of ETO, production planning that takes into account customer order and addresses it by involving all key functional areas such as design, engineering, procurement, production, and sales should lead to delivery of projects within agreed lead time along with the required quality standards. A critical aspect is the customer involvement throughout the process. However, implementing decentralized approach engenders flexibility, transparency and responsive, which in turn strengthen the impact of decentralized planning on project delivery. In contrast, implementing centralized approach is likely to stifle the impact of production planning due to the rigidity, sequential interdependence and the top-down nature of this approach. Accordingly, the implementation of digitalized planning solutions and collaborative approach can enhance the positive impact of decentralization and weaken the potential negative impact of centralization.

4 Discussion

What the best approach to the organization of production planning may be depends on the characteristics of the manufacturing system and its environment as well as the obstacles faced in the pursuit of achieving a delivery within the realm of its objectives. Nonetheless, the final choice of a production planning system eventually depend on how the production planning systems are managed, weighted and what is the nature of the tradeoffs between them. Clearly a decentralized planning approach may induce very different pros/cons compared to a centralized planning approach. For instance, decentralized planning often results in loss of efficiency with respect to centralized planning, while its pros often are recognized as increased agility in responsiveness to changes and customer demands, better commitment to goals, and increased motivation and well-being of employees [4, 14]. Thus, disagreement between different levels of coordination and autonomy between plants or quite different products require different attention. Looking at the organization of a planning system in isolation can yield counterproductive results, especially for ETO firms. Nevertheless, decision making and hence, planning is generally employed either centrally or decentralized where digital software solutions on a central level is deployed, while failing to integrate production planning in a collaborative manner. Unfortunately, firms often seem to make ill-informed production planning decision based on superficial software features rather than on a selection of features that are applicable for their production environment [10, p. 870]. This is rather interesting as the complexity embedded in ETO environments is omnipresent acknowledged yet – paradoxically – overlooked. Hence, many of todays' ETO firms still departure from a serial production planning philosophy [18], which might explain why the application of centralized and hierarchical production planning systems continue being the norm.

Based on extant literature and this discussion we claim that a decentralized production planning system is the most suitable when the level of uncertainties and complexities are high and thus requires continuous modes of organization, as is the case for ETO firms. Preferable deployed in a collaborative manner. If not, a decentralized approach can risk replicating some of the disadvantages that can be found in a fully centralized production planning system, as this too can result in obstacles in production progress tracking and coordination deficiencies along interdependent functions and thus also disentangle itself from the overarching plan. Nonetheless, its strengths in reducing variabilities and increase reliability in production planning systems due to aspects such as transparency and larger decision space, heightens its potential as a positive approach to embrace in planning practices for ETO firms.

5 Closing remarks and further research

The recognition of the dilemma of centralized vs. decentralized production planning is not new. However, critical aspects such as engineering and customer changes and non-collocated production plants impose additional aspects which can hamper the effectiveness of hierarchal planning systems. This is because in ETO changes in engineering can propagate, as there is no next product run, instead production is discontinuing, requiring engineering and production processes to be executed in parallel. And when operating with multiple plants the decision space of planner/headquarter might require different modes of organization. Hence, both these aspects act as important boundary conditions to the universalistic 'one size fits all' planning system.

Based on extant theoretical and conceptual groundwork, the study delineated potential implications and opportunities with centralized and decentralized planning approaches within the context of ETO and multiple production plants. Hence, the contradictory pressure for either decentralized or centralized approaches promote one-sided solutions [4] accentuating the crucial significance of our theoretical discussion also for practitioners. As such, our study provides opportunities for extending extant theory on centralized and decentralized production planning within ETO contexts, while providing a tentative framework for ETO practitioners that can be applicable when decisions concerning an (re)evaluation of production planning systems are to be made.

Although the findings of this study are interesting and warrants further discussions, a limitation with the study is the difficulty to maintain a neutral perspective [22]. Furthermore, our discussion can be argued simplistic, especially since there are different forms of (de)centralized production planning systems, as well as new technological advancements e.g., Industry 4.0 applications. Yet we claim that the question at hand will still be heightened as a centralized vs decentralized approach also when accentuated by the means of Industry 4.0 applications. For example, in cloud-based solutions the reaction to engineering changes in ETO as well as the responsiveness to changes in local conditions at multiple plants will not diminish, and new technological systems will still be designed and used by people. Thus, we encourage future research to also investigate how production planning will be affected from such views. Especially since Industry 5.0 seem to reinforce the element of human participation, perceptions and hence input of information to such systems.

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