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Technical Paper

A risk based approach to support the supplying of components in a *MTO* assembly process

Massimo Manzini*, Marcello Urgo

Manufacturing and Production Systems Division, Department of Mechanical Engineering, Politecnico di Milano, Milan, Italy

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ABSTRACT

Product customization is becoming more and more an option required by the customers and, when referring to complex items, pursuing this path could have a strong impact on the way companies have to manage the products and the associated processes. In this context, a *Make To Order* (*MTO*) and *Engineer To Order* (*ETO*) paradigms are viable approaches. Using these paradigms, the coordination between supplying and manufacturing has a prominent importance. A missing component during the production phase can cause significant delays and disruptions in the plans and, consequently, delays respect to the due dates negotiated with the customers. Due to the intrinsic uncertainty associated to the selection of customization options by the user, the supplying of the components and the production/assembly process, company managers addressing this coordination problem have to ground on risk measures supporting the selection of the right supplying option, aiming at minimizing the probability of missing components. In this paper, we present an approach to support this selection in the production and assembling of complex products grounding on the definition and calculation of two indicators, the *Risk Index* and the *Criticality Index*. The first one addressing the risk associated to the supplying of a component through different supplying alternatives, the second one providing an assessment of the criticality of the coordination between the supplying and assembling phases together with the specific risk aversion. An application to a real *MTO* industrial case is also provided addressing the production of machine tools.

1. Introduction and motivation

Manufacturing has to cope more and more with product customization and, thus, higher variety. Manufacturing companies need to re-design their products and the related production processes to be easily customizable and move towards a different organization paradigm where every product has characteristics to be specifically designed and manufactured, causing the *Make-To-Stock* (*MTS*) paradigm to be not suitable anymore. The *Make-To-Order* (*MTO*) model, where a product is manufactured only if an order has been placed, is a widespread approach to cope with these cases, evolving towards *Engineering-To-Order* (*ETO*), if the customization also requires a specific design of the product, besides the manufacturing.

A shift towards the *MTO/ETO* production paradigm has a significant impact on the operation phase, specifically in relation to production planning and scheduling, where the variability of production requirements (machines, workers, tools, times, etc.) has to match the available resources and related capability. Also the availability of components has to be managed in a rather different way. Highly customized products are typically composed of a standard set of components plus some where customization applies. During the assembly phase, the coordination between the supplying of components and the associated assembling activities is fundamental for the lean management of resources, time and space. An additional complexity in the coordination of material supplying and production activities is incurred in the production of complex products, e.g., instrumental goods, turbines, valves, etc., where many assembling operations are executed by human workers, thus entailing a certain degree of variability and uncertainty.

This paper is focused on the coordination between material supplying and production activities in *MTO/ETO* systems producing complex products. Specifically, the proposed approach addresses the risk of stock-out for different components taking into account its potential impact on the production and assembly process, also considering the intrinsic uncertainty of manually executed activities. Grounding on these considerations, a level of *criticality* is assigned to components with the aim to identify those whose shortage is most likely to cause a delay in the production process and, consequently, a possible delay of the delivery date agreed with cus-

* Corresponding author.
E-mail address: massimo.manzini@polimi.it (M. Manzini).

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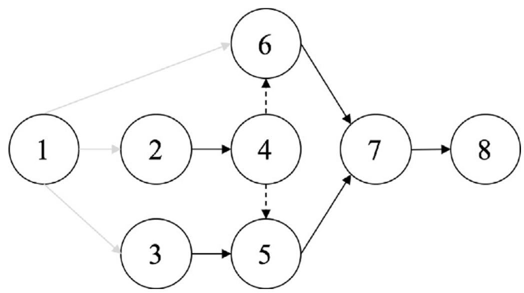

Fig. 1. *AoA* network representing an assembling process.

tomer. The calculation of components' criticality takes advantage of a project scheduling approach to estimate the time when specific components are expected to be needed to go on with the production process. This value is a stochastic variable due to the presence of the uncertainty affecting manually executed activities. The comparison with the corresponding supplier's lead-time provides a criterion to assess the level of criticality. *Criticality* is expressed in terms of two stochastic indicators that can be used by the company to reduce the risk of stock-out and optimizing the management of inventory and suppliers.

Section 2 provides an analysis of the related literature, while the complete problem statement is presented in Section 3 where the above-mentioned coordination problem is described with reference to the assembling of tailored machine tools. Section 4 and its sub-sections describe the proposed approach through five main steps. An application to a real industrial case is presented in Section 5. A final appendix reports detailed information on the products and processes addressed.

2. State of the art

The coordination of production and material supplying is key factor in the management of a production process. A stock-out of materials or components needed by the production/assembly activities is likely to impact the production causing delays and/or non-efficiencies. In addition, being able of addressing the uncertainties in both the production and supplying are relevant aspects to be addressed.

Some approaches are focused on the impact of unavailability of components and their impact, using an inventory classification [29,31]. Stanford and Martin [29] provide an inventory classification to manage the stock turnover in a multi-item inventory system with constant demand. The approach organizes items in different classes and manages each class as a single entity. In Tsai and Yeh [31], the same problem is addressed through an algorithm providing an inventory classification without relying on a fixed number of groups. This class of approaches only look at the demand of components without addressing the inherent connection with the manufacturing process.

An example of coordination between activities and materials is presented in [12], where a production transfer process is addressed using a structured procedure for the material planning to avoid costly production stops or delayed deliveries to end customers. In this paper only the specific case of production transfer is considered through a qualitative evaluation. Capacity planning in manufacturing processes is considered in Carvalho et al. [8] and Jodlbauer and Altendorfer [18], where the relation between available item capacity and inventory is studied in a multi-item *MTO* production system with uncertain customer requests. In these cases, only a strategic analysis is used, without considering the real process but only its nominal capacity requests. This is a relevant lack in the available literature since, in the production/assembly of complex products, the scheduling of the activities and/or their execution can be different, thus, the time patterns of nominal requests are often rather different from the real ones. For these reasons we address the *day-by-day* coordination between the execution of production activities and the availability of components, taking into consideration the different process execution modalities through the estimation of the distribution of the start/completion times of the activities.

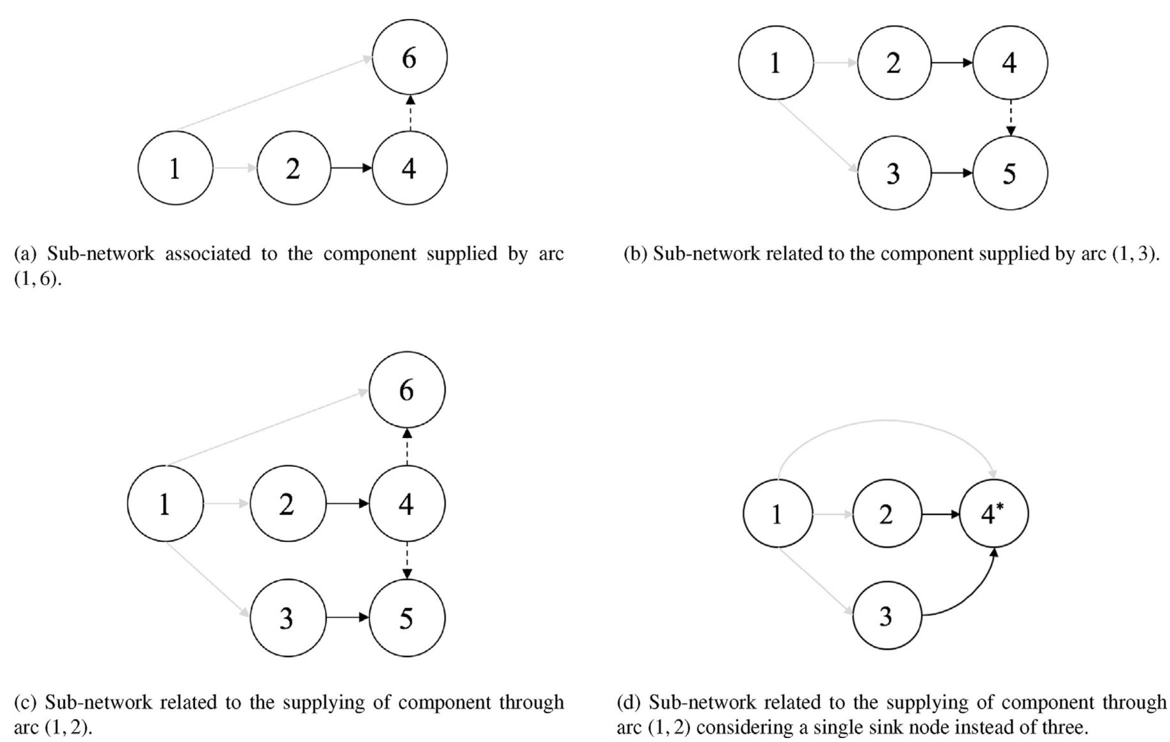

Fig. 2. An example of sub-networks identification for the three supplied components.