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Generation of Planned Orders and their Matching with Customer Orders in Multi-Variant Series Production

Jens Buergin[a]*, Julian Beisecker[a], Sebastian Fischer[a], Bettina Geier[a], Hansjoerg Tutsch[b], Stefan Mercamp[b], Gisela Lanza[a]

[a]*wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Kaiserstrasse 12, 76131 Karlsruhe, GERMANY*
[b]*flexis AG, Schockenriedstraße 46, 70565 Stuttgart, GERMANY*

* Corresponding author. Tel.: +49-721-608-44013; fax: +49-721-608-45005. E-mail address: Jens.Buergin@kit.edu

Abstract

Sustainability of production and supply chains can be achieved by efficient planning. However, customers' demand for multi-variant products and short lead times poses a challenge for automobile manufacturers not receiving customer orders in the mid-term planning horizon. To meet this uncertainty, this paper shall introduce an approach for anticipating customer orders by generating planned orders and for matching planned orders with incoming customer orders.
Planned orders enable the integration of sales planning, production planning and material requirements planning in the mid-term and short-term planning horizons. In conclusion, resources can be used more efficiently to fulfill customer needs.

Keywords: Integrated Planning; Order-Driven Planning; Option-Based Order Generation; Order Matching

1. Introduction

One challenge in multi-variant series production, as it applies for example to the automobile industry, is the utilization of production network capacities that are provided by making investments based on strategic decisions with variable market demands in terms of the quantity demanded of multi-variant products [1]. In catalogue mass customization, customers configure their product from a pre-engineered catalogue of product variants that are produced following a standardized order fulfillment process [2]. Regarding product variety it has to be distinguished between external variety, referring to the derivatives and option choices offered to the customer, and internal variety, meaning the variations of parts [3]. In build-to-order (BTO) (or assemble-to-order) production, the decoupling point between internal variety based on forecast and external variety based on customer orders is at final assembly [3]. Thus, lead times for production determine delivery lead times for customer orders [1]. In contrast, following a build-to-stock (BTS) strategy, products are assembled according to forecasts and thus external variety is not based on customer orders leading to the problem that inventories of finished goods are high and that customer requests that are different from those in stock cannot be fulfilled [3]. In order to combine the advantages of BTO and BTS, automobile original equipment manufacturers (OEMs) follow a hybrid order fulfillment strategy making use of both BTO and BTS [1]. Pursuing such a strategy, there is an "order freeze" being defined as the point in time when the product configurations of orders of a planning period are fixed in order to release them to production plants [1]. The share of capacity that is utilized by customer orders before the "order freeze" is BTO and the rest is BTS [1]. For the share of BTS, customer orders have to be anticipated by generating planned orders that are free to be matched with incoming customer orders later on [1]. The share between BTO and BTS is not the same for different markets as it depends on the behavior of the customers of a market as well as the proximity of a market to the production sites and the respective delivery times [4]. In the US, only 6% of the cars are BTO whereas in Europe 48% and in particular in Germany 62% are BTO [5].

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Planned orders may be generated directly by an OEM's central sales organization or by intermediaries in the distribution chain such as regional sales offices or local dealers [1]. The "order freeze" for order-driven short-term planning and thus the point in time when options of orders have to be specified for calculating the demand for parts, meaning material requirements planning for the precise call-off, is reached about one month before production [6, 7]. The call-off for parts is defined as communicating the need for material to suppliers that ensure short sourcing lead times based on long-term purchase agreements [8]. It follows a purchase-to-order logic in short-term planning if it is coupled with customer orders and thus not based on forecasts [8]. In the mid-term planning horizon, planning is forecast-driven and thus based on sales forecasts for quantities of models and for relative frequencies of options in different markets on a monthly basis [6]. A preview on the demand for parts is given as a rough call-off to suppliers between 18 to 3 months before production, but it will be fixed at the "order freeze" [6, 7, 9]. The longer the preview is given before production, the less reliable it is [6].

However, for complex, multi-variant products it is not possible to directly calculate material requirements based on forecasted quantities of models and forecasted relative frequencies of options in mid-term planning [7]. As parts typically depend on more than one option, Boolean algebra rules for the combination of options have to be considered [7]. Therefore, the planning of material requirements may be based on the BOM (bill of material) explosion of fully specified orders [7]. Thus, the generation of planned orders based on forecasts should not be delayed to short-term planning but should already be conducted for mid-term planning to enhance the adequacy of the rough call-off.

In conclusion, this paper introduces an approach for mid-term planning based on planned orders that cannot only be used for mid-term planning of material requirements, but also for mid-term production planning, i.e. the assignment of planned orders to final assembly plants and periods such as weeks, days and cycles in assembly lines. Thus, the approach resolves planning inconsistencies between functional units of a company such as procurement, production and sales. Moreover, it allows for consistency between mid-term and short-term planning as not only short-term but also mid-term planning is based on orders. Therefore, a methodology for the generation of planned orders regarding products with a complex product structure such as automobiles and a methodology for matching of planned orders with customer orders are presented.

The paper is structured as follows: In section 2, a literature review on order fulfillment strategies, on product structures and documentation as well as on forecasting material requirements is provided. Section 3 proposes an approach for order processing as well as methodologies for the generation and for the matching of orders. A summary and outlook is provided in section 4.

2. Literature Review

2.1. Order fulfillment strategies

Since purchasing and assembling parts usually takes longer than the order lead time expected by the customers, some of the processes must be made independent from customer orders. Along the flow of material, the point whose following processes are connected to a customer order is called the customer order decoupling point (CODP). The location of the CODP is the basis for distinguishing the various order fulfillment strategies such as build-to-order (BTO) and build-to-stock (BTS). [10]

Due to the characteristics of the two strategies described, it is difficult to determine a dominant CODP. Therefore, Brabazon and MacCarthy [11] described a concept, in which a customer order can be fulfilled by any kind of inventory, meaning that for each customer order received, a suitable product from the order fulfillment pipeline is identified and assigned to the customer. This pipeline includes all products that are in stock and all planned orders that have not yet been assigned to customers. Since the matching of customer orders with planned orders can occur along the entire pipeline, the CODP is floating and not fix. When planned orders are generated, the customer behavior is anticipated as the coupling with customer orders, i.e. the matching, takes place later on. Therefore, the respective strategy is called Virtual-Build-to-Order (VBTO). The greater the quantity of product variants, the lower the probability for finding a suitable planned order for matching with an incoming customer order. Thus, for successful matching, it is necessary that the specifications of the planned orders can be adapted to the ones of the customer orders. This potential for adaptation is dependent on the position of the planned order within the pipeline because the nearer the order approaches to the time of assembly, the more difficult it is to change its specifications. [11]

Due to the individual decoupling point of VBTO, the delivery requests of customers can be considered significantly better than in the ordinary BTO strategy. In addition, the call-off can be based on planned orders. Compared to the BTS strategy, customers have greater influence on the specification of their product and inventories of finished goods are reduced. [11]

2.2. Product structure and documentation

Product structures can be described graphically as trees that can be converted into tabular forms such as bills of materials. Common trees used for product structures are the feature tree and the variant tree.

The feature tree consists of three levels with the product itself on the first level and its features, i.e. option groups, on the second level. The third level comprises the characteristics of the features, i.e. options. Therefore, the height of the tree is short. Each product variant is described by the selection of several leaves. Constraints regarding combinations of specific options have to be defined between nodes. [12]

In the variant tree, each level is dedicated to one product feature, i.e. option group, so that one feature characteristic, i.e. option, has to be chosen on each level. Thus, one product variant is represented by a path through the tree from the root to one of its leaves. Consequently, the number of leaves equals the number of different product variants. Combinatorial constraints can easily be integrated into the variant tree by eliminating nodes that cannot be chosen based on its predecessor nodes. Variant trees are quite complex as each option appears in the tree on each buildable path which