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# Using hierarchical pseudo bills of material for customer order acceptance and optimal material replenishment in assemble to order manufacturing of non-modular products

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**Abstract**

In assemble-to-order manufacturing, often product families with many options and features are offered to the market. Demand for an individual option or feature can be quite low and uncertain. The efficient checking of materials availability during customer order acceptance, and the materials requirement planning are crucial for effective control in this type of industry. Traditionally, modular bills of materials are used for this purpose. If interdependencies exist between features and options in the product family, modular bills are inadequate; instead generic bills of material can be used to model the production options available in a product family. In this paper we develop a variant of the modular bill of material, called the hierarchical pseudoitem Bill of Material, which is the mirror image of the choice tree in the generic bill of materials, and which can be used for checking materials availability, for allocating materials to customer orders, and for materials replenishment. Furthermore, we propose a model to optimize the master production schedule levels for options and features that drive the material replenishments process. The optimization aims at balancing the stock keeping costs of specific parts for options, with the revenues that result from selling products variants with those options. © 2000 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

During the past decades the discrete assembly industry has been faced with an increased product variety, shorter product life cycles and a fragmentation of markets. Tighter competition and the emergence of buyer markets have forced companies to offer a continuously growing and changing product variety to prevent losing market share [1]. As a result more than a few million product variants are already offered in the automobile, aviation and medical equipment industries [2]. What's more, in non-assembly types of industries like insurance, banking, beverage and personal care, this proliferation of product variety can nowadays also be discerned [3].

Unfortunately, these volatile market conditions in the discrete assembly industry have induced

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a number of problems. Wemmerlöv [4] indicates four problem areas with regard to material coordination in the assembly industry:

(a) *material structuring*. A proper data storage of product structures is important to control production and supply of materials. In this context a large product variety will increase the number of end product variant structures that have to be stored and maintained and consequently the complexity of the data storing process.
(b) *forecasting*. Forecasting demand for each end product variant, becomes an almost impossible task when many variants are involved because the average demand per variant will be low.
(c) *buffer allocation*. A high product variety thus leads to a high demand uncertainty. This uncertainty has to be buffered against with safety stocks. The chances that these stocks are unbalanced and thus will lose their effectiveness, will increase in case of high product variety.
(d) *order acceptance*. Each final product variant is often a combination of subsystem variants. Upon arrival of an order all the required subassembly variants have to be checked on their stock availability. Fast and integral stocks checks are essential to enable short feedback cycles concerning planned delivery times to customers.

Wemmerlöv further states that assemble-to-order (ATO) manufacturing is relatively the best manufacturing strategy to deal with a high product variety because it "defers the commitment of material and capacity as long as possible". An ATO strategy implies the final assembly of end product variants upon arrival of a customer order from subsystem variants. Important logistic functions that should be addressed while adopting this manufacturing strategy are therefore product structuring, buffering against uncertainty, material supply planning and customer order processing.

The response to these problems have been threefold.

Firstly, the production and final assembly processes are designed such that the end product variety can be realized in the final assembly phase (design for assembly, modular product design, postponement of product specificity).

Secondly, the final assembly processes, and sometimes also the subassembly processes, are transformed from batch processes to flow processes. This allows for the successive assembly of all end product variants with batch size one (from a multi-model assembly line to a mixed model assembly line). The material supply to these mixed model assembly lines requires a very tight coordination of the different components and subassemblies needed for each end product, to the different positions in the assembly line.

Thirdly, special bills of material are developed to support the customer order acceptance process and the materials supply process. Generally, a customer does not express his requirements in the technical characteristics of the product, such as motor type, brake type, transmission type, etc., but in terms of functional features such as horse power, color, accuracy, speed, etc. A manufacturer may offer a wide range of products, some of which may fit with the functional specifications of the customer. Searching through the product family to look for the best fitting product can be a time consuming process, unless the search process is efficiently organized. The normal solution to this problem is to make use of features and options to identify a specific variant within a product family. A feature can be viewed as a product family characteristic for finished products. Each feature, e.g. the color of a product, is associated with a set of mutually exclusive options. An option is, therefore, a value assigned to a characteristic that represents a property of a product that is relevant for a customer. In this case, the master production schedule items are typically found at the level of major components or important subassemblies [5] that represent mutually exclusive (combinations of) options and features. Forecasting the demand for finished products is often based upon the forecasted demand for the various options. Translating the option forecast to MPS item forecasts is traditionally accomplished by using so called modular bill of material. The MPS items are grouped in planning modules in a modular bill of material. A planning module, therefore, becomes either a set of parts needed to manufacture a finished product with a certain