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An optimization model for selecting a product family and designing its supply chain

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Abstract

When designing a new family of products, designers and manufacturers must define the product family and its supply chain simultaneously. At the very first step of the design process, designers propose various solutions for the set of variants of a product family and their bill-of-materials. The second step is to select some of these variants while choosing the architecture of the supply chain. A mixed integer linear programming model is investigated that optimizes the operating cost of the resulting supply chain while choosing the product variants. This work is applied to the problem of an automotive supplier.

Keywords: Supply chain management; Product family design; Supply chain design; Mixed integer linear programming (MILP)

1. Introduction

Nowadays, the growing demand for customizable or configurable products involves an increasing number of product variants and a growing complexity of products while controlling the product costs and the customer lead-time. This task becomes more difficult when the supply chain layout has a significant influence on operating costs. Consequently, when designing a new product family, a consistent approach is necessary to quickly define a set of product variants and their relevant supply chain, in order to guarantee the customer satisfaction and to minimize the total operating cost of the global supply chain.

This paper proposes a design approach that allows to define simultaneously a product family and its supply chain while facing a customer demand with a large diversity. Between "*Product Design*" and "*Supply*

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Chain Management ", our simultaneous approach is closely related to the field of "*Concurrent Engineering*" [25] and more accurately to a "*Design For X* (*DFX*)" approach [15], where *X* is the *Supply Chain*.

Design For Supply Chain (DFSC) or Design For Logistics (DFL) basics have been defined by Lee in [16,17]. These works underlined various interests in adapting the design of a product family in order to enhance the costs and lead-time of a given supply chain. They mainly quantify how the manufactured diversity can be decreased and the consequences on safety stocks cut down thanks to the following means: various kinds of postponement of a product variant (time, place or form postponement) [17,18], product and process modularization or standardization [7], operation reversals that cause a component reversal in the bills-of-materials [19]. More recently, Van Hoek [26] synthesized the developments of postponement applied to a supply chain. Anderson [1] and Pine II [24] also underlined the integration of these concepts in order to propose mass-customizable products.

Our purpose is to help the designers of a product family in making design choices and evaluating the consequences of their choices on the layout of the supply chain that will deliver the products.

Therefore, we consider a two-step iterative process (Fig. 1):

- The first step, the bill-of-materials provider step, easily and quickly defines error free bill-of-materials for a set of pre-identified customer requirements. It is a pure product design process. It is only considered at the preliminary design step that deals with some design principles and product architectures. It generates many product variants so that a selection can be made in the second step.
- The second step optimizes the compromise "over equipment cost/reference management cost", through the simultaneous selection of (i) the supply chain (where to manufacture, to assemble and to store) and (ii) the product variants of the product family.

The process is interactive because knowing the product variants selected at the second step can help the product designers in adjusting, during the first step, the design principles and the set of customer requirements.

Our purpose in this paper is not to explain how to handle the first step. But an example of a tool for supporting the bill-of-materials process using the analogy with a configuration process can be found in [14]. We focus on the second step, and therefore it is necessary to specify:

- how to depict, through a generic bill-of-materials, the product diversity resulting from the first step (Section 2);
- the model that enables to make the various choices (Section 3).

Finally an application dealing with the design of a wiring harness family for a car manufacturer will be depicted in Section 4.

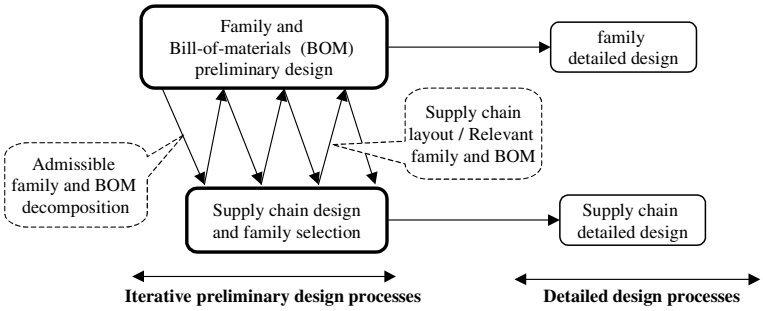

Fig. 1. A two-step iterative process for product family and supply chain design.