PRODUCT FAMILY DESIGN WITH CUSTOMER PRODUCT PROCESS AND LOGISTICS DECISIONS

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ABSTRACT

Design and management of product variety is a typical problem in product portfolio management. This paper presents computer software (ASDN) for cost based analysis of product platforms and product portfolio analysis. The approach is based on modelling logical bill-of-materials trees and assigning cost and logistics information on each component. Product families are modelled as hierarchical component lists, which may contain logical ports such as AND (Assembly) and OR (alternative component). Each product has a demand and standard deviation of demand. This information is then distributed with components which have an embedded with cost and volume information. By combining the product structure information with volume, cost and replenishment time, the user of variant analysis tool may find answers for following questions: (1) What is the cost of adding a new variant into a product? (2) How much is the benefit of replacing a specialized component with a standardized one? (3) How much inventory replenishment time affects to total product cost? (4) How to improve the routing structure (logical BOM) from product architecture point of view? The paper aims to connect product family design with logistics analysis by demonstrating some possible analysis.

1. INTRODUCTION

Product variety is increasing in many industries. While product life-cycles are still shortening, the manufacturing networks have become dispersed. In order to analyse the problems caused by this change in environment one needs to combine the methods of logistics with product design analysis. Traditionally, the field of logistics studies the process of planning, implementing and managing flow and storage of raw materials, work-in-progress, finished goods from the point of origin to point of consumption for the purpose of fulfilling customer requirements. As management of logistics becomes more complex and distributed,
more knowledge that can advance a company’s operations also in field of design-for-logistics is needed. This creates the need for cross-disciplinary applications.

There are several questions are related to issue how to manage the product variety in dispersed global networks. The practical questions asked by product and factory managers include: (1) How to integrate product design with supply demand network design? (2) What is the cost of adding a new product variant in product portfolio? (cost vs. benefit) (3) How to estimate the payback of new product introduction by estimating the total manufacturing costs. (4) Which parts should follow make-to-stock and which should go to engineer-to-order? This paper introduces ASDN software tool, which can be used to analyse product structures from logistics point of view and support decision making at product portfolio design phase.

2. PRODUCT VARIETY

Product variety and its effects on manufacturing productivity has been discussed widely in mass-customization literature. Pine [1] [2] makes a distinguishing between high variety and mass customization strictly. High variety is defined as demand volume variety with fixed configuration while mass customization is how to produce a product for customer exactly what they want and future supply chain network should be composed against mass customizing demand. Furthermore, Mikkola et al. [3] and Salvador et al [4] support their idea by introduce modularity in order to support postponement. Philosophical stone for those applications has been established by Pine and Gilmore [2] who divide customization into four classes they are collaborative, adaptive, cosmetic and transparent.

Pine’s [1] definition is also supported by Davis [5]. The author describes mass customization property is reflected by holography where “if the image is broken, any parts of it will reconstruct the whole”. The insight is information should available for every part within the whole system. For this reason supply chain strategy for mass customization should be focused on the entity properties. For instance modularity is intended to components standardization while postponement is subjected to reduce lead time by move point of differentiation closer to delivery point [6]. In short, if entity is variety then modularity should be done in order to reduce process variation. In other side, postponement is delivered while components have slime variety in order to reduce lead times.

Postponement and modularisation strategies have effects on logistics. For this reason high volume electronics products tend to have integrated product structure and modular
architectures such as bus or slot types are used in low volume products. Decisions on product architecture have an impact on part commonality [7], which a key driver of material flow.

Analyzing the decisions on product design and architecture is about mapping functions of product with physical component. This may be analyzed also from logistics point of view by combining the information from several domains: (1) product parameters from customer point of view, (2) customer demand for each parameters, (3) constraints, and (4) part designs.

3. SOFTWARE

ASDN Product Variety Analysis is part of ASDN logistics software, which is an open source modelling tool for logistics problems. ASDN software provides functionality for cost based analysis of product platforms and product portfolio analysis. The approach is based on modelling logical bill-of-materials trees. This means that products are modelled as hierarchical component lists, which may contain logical ports such as AND (Assembly) and OR (alternative component). Each product has its highest level a demand and standard deviation of demand. This information is then distributed with components which have an embedded with cost and volume information.

3.1 Elements structure

Modelling is initiated by defining product family, which can be connected in hierarchically to lower level elements, which as (1) product parameter (e.g. colour), (2) parameter value (e.g. colour – yellow), (3) component – a physical component with cost and replenishment time, (4) port – a logical port such as “assembly” or “OR” describing configurability or optionality of next level elements. Product family level has mandatory demand attributes product annual demand and standard deviation. The user can add several product families into the same tree view, which results product portfolio. Figure below shows the user interface of the analysis tool. The currently selected product is displayed on the right hand side of the screen. Most of the important information is stored on the component level. Components may inherit the properties from component groups, which are made for easier maintenance of large product structures.
Fig 1. User interface of bill-of-materials analysis shows portfolio of three product families.

3.2 Components

Component data is the basis of all analysis within the variant analysis. The parameters are divided into categories of (1) customer, (2) product, (3) process, and (4) logistics. Figure 1, right hand side shows user interface and potential input values for attributes used in calculation logic. The component attributes are related to lead-time, costs, profit and inventory.

3.2 Ports

Ports connect components into groups by assembly or selection options. Ports may have quantity multipliers and costs for port operation (such as assembly cost). Ports may be connected to network phase, such as stocks (node selection). Ports are used to derive volume for each of the component in calculation algorithm.

3.3. Calculation logic

The ASDN software calculated demand top-down for each component based on product family demand parameters and port-structure. Demand variation can increase according to bullwhip effect parameter and for shared common components demand variability can dampen according to square root law. The system can take into account various cost parameters such as batch sizes and learning effects. Fig 2 shows demand calculation principles for cases of single product family and product portfolio level.
Product variety analysis
Single product family

Component A Demand = 100% (from Assembly 2000 pcs / a)
Component A StdDev = PF StdDev * Main component Std.dev.

Total Cost = Assembly cost + \sum (Component cost * Component PF volume)
PF Demand = 1000 pcs
PF Std.Dev. = 10%

Component A
2000.0 pcs - 100.0€

Option
1500.0 pcs - 100.0€

Main component Demand = 100% (from PF 2000 pcs / a)
Main component StdDev = PF StdDev * Std.dev.

Component A Demand = 100% (from Assembly 2000 pcs / a)
Component A StdDev = PF StdDev * Main component Std.dev.

Fig 2. Calculation logic for demand calculation within product family and portfolio.
4. ANALYSIS OF RESULTS

The overall cost effect may be visualized from the reports functionality of the software. This screen shows each component, demand %, total calculated volume, purchasing price and assigned fixed costs as well as total costs. The main views are: product view and entire product portfolio, which shows all the products. Key measures that ASDN software produces are (1) volume vs. commonality graph for each component, and (2) component cost graph. The connection between component volume and commonality (how many percent of end products use the component) may be analyzed in volume / commonality view. The upper part of the graph shows volume sorted list of components. The lower part shows the commonality measure in product family level in same sequence. Component costs graph shows components sorted from most expensive to cheapest components. The total cost is divided into groups: material, direct work, setup, capital cost, depreciation, and annual fixed costs.

Fig 3. Demand, costs and commonality are calculated for each component.

5. CONCLUSIONS

ASDN provides a basic modelling and analysis tool for product designers to consider logistics point of view. The software has been applied in electronics product family design, but it could suite in industries where production is based on assembly type of operations. The tool can show analysis results on single product family with configurability and uncertainty in variant demand, but also on product portfolio level, where common components are shared between product families. The results of using tool
can include improved cost structure, postponement decisions, reduced component demand variability and cost efficiency in product mix range.

The bill-of-materials view can be combined to structure of supply demand chain producing the products. This could help visualising where inventory will be carried. As Holweg and Pil [8] have demonstrated inventory profile in automotive industry, the effects caused by product structure and order decoupling point decisions can be wide. According to this study both the car manufacturers and the first-tier suppliers have nearly no work-in-process inventory. Since decades, automotive manufacturing is push-oriented, creating huge inventory at the delivery end of the chain, products waiting for the right customer. This is naturally the most expensive place to gather inventory. The other inventory top was the ingoing inventory at first-tier supplier. In some cases, the inventory of bought-in parts was up to 60 days. Suppliers tend to hold a buffer to cope with demand fluctuations and last-minute changes to demand forecasts. To a certain degree, this inventory is also a function of product variety allowed to the customers. That the inventory does not show in the books of the manufacturer (it is held by first tier suppliers, but for same reasons: variety and fluctuation of demand) does nevertheless not make holding this inventory cheaper: all inventory has costs that must be paid in full. For fast response manufacturing chains a combined analysis of logistics networks and bill-of-materials is needed. ASDN as an open source software [9] tool can provide a platform for this.

REFERENCES

