Int. J. Production Economics 166 (2015) 72–84

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Late customization strategy with service levels requirements

Thomas Ngniatedema [a,*], Murali Shanker [b,1], Michael Y. Hu [c,2], Alfred L. Guiffrida [b,3], B. Eddy Patuwo [b,4]

[a] Department of Business, Kettering University, 1700 University Avenue, Flint, MI 48504, USA
[b] Department of Management & Information Systems, Kent State University, Kent, OH, USA
[c] Department of Marketing, Kent State University, Kent, OH 44242, USA

ARTICLE INFO

Article history:
Received 22 August 2014
Accepted 3 April 2015
Available online 23 April 2015

Keywords:
Product customization
Delayed product differentiation
Inventory service levels
Bayesian Belief Networks

ABSTRACT

Both supply issues and interaction between various stages of a production network are common occurrences in product customization under a delayed differentiation strategy. This paper studies non-decouple systems for product customization in the context of a single-market segment under a delayed differentiation strategy by incorporating supply issues and interaction between various stages of a production network. We analyze two alternatives for customizing two individual products. One alternative is the contractual obligations for raw materials delivery where the supplier is responsible for maintaining certain inventory service levels agreements. The other alternative is the customer demand requirements where the manufacturer is responsible for maintaining certain end-products service levels to prevent customer erosion. We characterize the service level requirements in both scenarios and determine the optimal customization point of the production network where the practitioner can operate at minimum cost. We use a Bayesian Belief Networks method to model interaction between stages of the production network and derive the inventory service level requirements. A mini-case involving the customization of a personal desktop computer is used to illustrate the applicability of this framework. We also compare the benefits of delayed product differentiation under non-decouple systems and the traditional decouple systems and provide insights into how firms can choose the right strategy to effectively compete.

Published by Elsevier B.V.

1. Introduction

The increasing customization needs in today's globally competitive market pressurizes firms to continually improve customer service while simultaneously reducing costs. In response to these pressures, many organizations have adopted delayed differentiation as foundation of their product customization strategies. The relationship between delayed differentiation and mass customization capabilities is well documented in the literature (see for example Cheng et al., 2010; Feitzinger and Lee, 1997; Lee and Tang, 1997; Ngniatedema, 2012; Peters and Saidin, 2000; Wang et al., 2012).

Delayed product differentiation (DPD), – also known as form postponement (FP) or late customization – is a type of postponement used by practitioners to delay activities, such as labeling, packaging, assembly, or manufacturing with an aim to move the point of individual product customization downstream in the supply chain (Zinn, 1990; Zinn and Bowersox,1988). Under a FP strategy, the task of differentiating a product for a specific customer or a particular market is delayed until the latest possible point in the production network when components with different technical specifications or products with diverse functionalities are created (Lee, 1996; Swaminathan and Lee, 2003; Van Hoek, 2001). By keeping products in their generic forms, FP can also be used to delay the customization of goods and services as long as possible until the customer orders are received (Lee, 1996). Past researchers argue that postponing the final product customization provides firms with compelling benefits. At its most basic form, FP exploits the variance reduction through a risk pooling effect, by reducing the required safety stock to meet a given service level (Lee, 1996; Lee et al., 1993; Pollard et al., 2008; Wang et al., 2012). FP can be implemented in contexts in which a buffer inventory is kept after each processing stage-as assumed by Lee and Tang (1997)-as well as in contexts in which only finished goods inventory is kept (Aviv and Federgruen, 2001; Lee, 1996; Ma et al., 2002).

Different ways in which form postponement can be pursued, each with different costs and service performance impacts can be found in the literature. Lee and Tang (1997) propose a DPD model in which two end products can be manufactured in N stages in the

* Corresponding author: Tel.: +1 810 762 7956; fax: +1 810 762 9944.
E-mail addresses: tngniate@kettering.edu (T. Ngniatedema), mshanker@kent.edu (M. Shanker), mhu@kent.edu (M.Y. Hu), aguiffri@kent.edu (A.L. Guiffrida), epatuwo1@kent.edu (B. Eddy Patuwo).
[1] Phone: +1-330-672-1165; fax: +1-330-672-2953.
[2] Phone: +1-330-672-1261; fax: +1-330-672-5006.
[3] Phone: +1-330-672-1158; fax: +1-330-672-5006.
[4] Phone: +1-330-672-1163; fax: +1-330-672-5006.

http://dx.doi.org/10.1016/j.ijpe.2015.04.001
0925-5273/Published by Elsevier B.V.

production process, starting with some common operations up to a point where products are differentiated according to each individual customer tastes or market segments. They model a generic manufacturing system which may include not only assembly, but also fabrication. As in Trentin et al. (2011), Lee and Tang (1997) assume that for a given period, when information about product demand distribution is known or forecasted, the number of components needed at each stage of the assembly line is directly related to the average demand of the end products.

Lee and Tang's (1997) work is useful for analyzing the costs and benefits of delayed product differentiation. However their paper suffers from some weaknesses. First, Lee and Tang (1997) assume independent treatment of work-in-process inventories installations in the production network using a constant service level. In product customization for example, speed and operational flexibility are two key competitive priorities, and simply maintaining a high service levels at each buffer to reduce the interaction between stages in order to control the production "locally" for each of the stages is not applicable to all situations (Kakati, 2002; Ngniatedema 2010, 2012). Hence, this "decoupling" approach gives rise to inaccuracies in assessing the value of delayed differentiation (Ngniatedema et al., 2015). Second, Lee and Tang (1997) ignore supply issues in production systems operating under a DPD strategy (Ngniatedema 2010; Ngniatedema and Chakravarthy, 2013; Ngniatedema et al., 2015). However, uncertainties are major threats to supply chain practitioners (Lee and Billington, 1993), and ignoring supply issues when implementing a DPD strategy can lead to possible sunk costs. In vertically integrated supply chain structures for example, most companies contract their needed components from external suppliers whereas other companies manufacture all of their components in-house. Each of these situations has an impact on the value of DPD strategy (Ernst and Kamrad, 2000). In the literature, a number of authors study an extension of Lee and Tang's (1997) by incorporating supply issues in their models (e.g. Ma et al., 2002; Hsu and Wang, 2004). However, these streams of research also analyze a DPD strategy under constant service level assumptions.

The paper herein can be viewed as an extension of the literature, building from Lee and Tang's (1997) model to propose two complementary alternatives for production systems which are operating under a DPD strategy. First, we consider supply issues in DPD strategy in two alternatives by integrating some supply risks which are common in supply chain and affect late customization decisions. In the first alternative, we model the situations where raw materials can be sourced from external suppliers on contractual basis whereas in the second alternative, we consider the situation where raw materials can be manufactured in house for vertically integrated companies. In our second contribution, we study and compared the benefits of DPD under decouple systems and non-decouple systems and examine how, under contractual agreements between the manufacturer and the suppliers, the choice of the service levels from the supply side affects the risk of stockout at each stage of the production network. We find that these service levels erode as the customization process moves downstream the supply chain, therefore allowing dependent treatments of work-in-process inventories installations in the production network in which inventory service levels are not constant, an approach which affects late customization decisions. We show that during product customization, interaction exists between various production stages, so that the customer service levels requirements at the finished products stages propagate upstream the production network and are subject to variation due to supply chain uncertainties. These two special cases complement the decoupling approach found in the literature where inventory installations along the supply chain may be treated independently from one another (e.g. Lee and Tang, 1997; Ma et al., 2002; Hsu and Wang, 2004). To model the interactions between stages of the production system and to quantify the inventory-service trade-off at each stocking point, we use a Bayesian Belief Networks (BBNs) methodology (Ngniatedema, 2010).

We also contribute to the literature by introducing two additional costs components which are likely to impact the total customization cost. The first cost component results from the buffer inventory (coming from the supplier side) at each but the last node of the production network. The second component provides an update to Lee and Tang's (1997) model to match each unit of the customer demand to the desired number of dependent components in the bill of materials. Finally, we determine the total operational cost of two product variants to examine the most effective way in which a firm can defer or delay product customization at minimum cost in the context of a single market segment. To illustrate the applicability of this framework, we use an example involving the customization of a personal desktop computer and provide insights regarding the determination of the point of the production network where products can be customized with the most pay-off.

2. Background literature

We focus on stochastic models for evaluating DPD strategy in the context of product customization with emphasis to inventory service levels requirements and cost management. Even though the literature on this stream of research is rapidly growing, an exhaustive review of these bodies of literature is beyond the scope of the present paper. Hence we provide only a sample overview and more careful review of past research findings relevant to our work.

Lee and Tang's (1997) study formulate a cost model to analyze the benefits of DPD in a production and distribution system for a single market segment. They model a system that manufactures two products in N-discrete stages, starting with the first k operations which are assumed to be common for the two products. Lee and Tang (1997) assume inventories of semi-finished products can be held at different points of the process with additional considerations of other factors such as design, processing costs and production lead times. They use the α-service level – defined as the immediate (i.e., off-the-shelf) availability of all the components required to assemble a unit of product – for the computation of safety stocks inventories at each stage of the network under a base-stock inventory policy (Forza et al., 2008). In their model, information about a product's demand distribution for a given time period is known or forecasted, assumed to be normally distributed; thus allowing the same degree of customer service to be maintained for different anticipated stock levels of the assembly line. Lee and Tang's (1997) model consists of four cost factors: (1) the total average investment cost, (2) the total processing cost, (3) the total work-in-process (WIP) inventory cost and, (4) the total buffer inventory cost. The WIP is a generic product up to the point of the production process where it is customized into the different end-products. After the point of customization, the WIP is a partially completed product (Lee and Tang, 1997).

A number of authors extended Lee and Tang's (1997) work. For example, Garg and Tang's (1997) model analyzes a production system with two product differentiation points with focus on inventory costs management. Lee (1996) and Garg and Lee (1998) also formulate few cost models for analyzing the point of product differentiation. A two-phase production system was introduced by Aviv and Federgruen (2001). They model a system in which common products are manufactured in the first phase whereas product differentiation is delayed in the second phase with aim to manage costs. Other authors advocate the importance of supply issues in DPD strategy while extending Lee and Tang's (1997) paper, but they also assume constant service levels in their papers. Ma et al. (2002) for example analyze component commonality and postponement in a multistage multi-product assembly system.