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Integrated management of inventory and production systems based on floating decoupling point and real-time information: A simulation based analysis

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ABSTRACT

Globalisation has transformed market conditions reducing lead times and increasing both the degree of product differentiation and price competition. To cope with this issue, new hybrid order fulfilment strategies have emerged which integrate the Make to Stock (MTS) and Build to Order (BTO) strategies, and whose aim is to simultaneously improve opposite objectives, such as the stock level and the lead time. Furthermore, companies face frequent challenges of sharing updated information and avoiding the lack of coordination between the different company subsystems. This work focuses on relatively recent fulfilment strategies based on the Floating Decoupling Point (FDP) which uses real time information to operate. The main objectives of this work are the study of the influence of different sources of real-time information about the available products and select the most suitable configuration of these systems, regarding the inventory control policy and the source of real-time information. The stochastic nature of the process makes simulation an appropriate tool to achieve valuable results. The simulation studies have been carried out following a full factorial Design of Experiments (DoE). Experimental results show that the strategies based on the FDP are very sensitive to the real-time information. These systems achieve the best performance when the inventory control policy uses simultaneously demand forecasting and real-time information of available products corresponding to the Work-In-Process (WIP) and Finished Goods Inventory (FGI). In contrast, system performance deteriorates significantly when real-time information of available products in the WIP has not been taken into account.

1. Introduction

Globalisation causes different effects on markets, among which are changing demand of more and more differentiated products, more competitive prices and tighter deadlines (see for example mass customization discussions in Alford et al. (2000), Duray (2002), MacCarthy et al. (2003), Brabazon and MacCarthy (2004b) or Silveira et al. (2001)). Given this environment, companies need to become more efficient, achieving higher production flexibility, improving delivery reliability and reducing system costs, including inventory costs. In addition, companies face a frequent challenge concerning the lack of coordination between their different subsystems. Among the consequences of these problems both the increase of the variability of inventory levels and the increase of the delivery delays are especially important.

The different Order Fulfilment Strategies (OFS) based on a single decoupling point -as Make to Stock, Shipment to Order, Packaging/Labelling to Order, Assembly to Order (ATO), Build to Order, Buy to Order, and Engineering to Order- do not aim at simultaneously reducing inventory levels and delivery times (see the review of postponement strategies by Yang et al. (2004)). For this reason, in recent years new hybrid order fulfilment strategies have emerged which integrate MTS and BTO strategies (see Calle and Gonzalez-R, 2012; Kalantari et al., 2011; Rafiei and Rabbani, 2011; Meredith and Akinc, 2007; Kerkkanen, 2007; Brabazon and MacCarthy, 2006). The most common studies of these strategies consist of the development of policies for the different production-delivery stages, such as the development of policies for the production planning (Köber and Heinecke, 2012; Rafiei and Rabbani, 2011; Hemmati et al., 2009; Perona et al., 2009; Zaerpour et al., 2008; Kerkkanen, 2007; Soman, 2004; Rajagopalan, 2002; Olhager, 2001), for the programming of production and inventory (Kalantari et al., 2011; Corti et al., 2006; Gharehgozli and Rabbani, 2006; Jiang and Geunes, 2006; Kaminsky and Kaya, 2006), or for the sequencing of the production (Wu et al., 2008; Soman et al.,

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2007; Chang et al., 2003; Federgruen and Katalan, 1999).

Among these systems, two new systems based on the FDP have emerged; the so called Virtual Build to Order (VBTO) and Improved Virtual Build to Order (*i*-VBTO) systems. These systems arise in the automotive sector, where major vehicle manufacturers (VM) offer a large number of potential variants (Brabazon and MacCarthy, 2004a; Fredriksson and Gadde, 2005; Meyr, 2004). These manufacturers operate with extensive product pipelines, whose manufacturing lead times exceed their customers' tolerable waiting times (Brabazon and MacCarthy, 2004a, 2004b), why they are forced to produce essentially to forecast (Brabazon and MacCarthy, 2004a). The idea of VBTO (see Agrawal et al., 2001; Brabazon and McCarthy, 2004b) arises as a strategy with the ability to tolerate greater sequence variation through assembly flow shops with minimal cost overheads, by taking advantage of the large size of the production line. The basis of this strategy is to serve customers from anywhere in the inventory (the customer is served directly from the FGI. If products are not available in the FGI, the semi elaborated product is searched for in the WIP and assigned to the customer). The previous studies of VBTO have shown the capacity of adaptation to the variability of the demand of the studied scenarios. An important disadvantage is the generation of long streams of identical products inside the production line (see Brabazon and MacCarthy, 2006), which provokes imbalances between the quantities of available products for each product type.

Subsequently, Calle and Gonzalez-R (2012) proposed the so called i-VBTO system, which incorporates to the basis of the VBTO system a previous stage for the inventory control aimed at avoiding imbalances of products availability. A key issue to ensure adequate delivery times is the availability of balancing product inventories.

The literature related to the systems based on the FDP mainly contains studies about the influence of several factors on the performance of the systems: the size of the production line (Brabazon and MacCarthy, 2006), the size of the product-mix (quantity of variants) (Brabazon and MacCarthy, 2006), the search sequence in production lines (Brabazon and MacCarthy, 2006), the impact of the two particular types of flexibility (Brabazon et al., 2010), a new method for controlling production orders (for the MTS mechanism) (Calle and Gonzalez-R, 2012; Calle et al., 2014), and the influence of different demand patterns (Calle et al., 2014). These strategies offer many avenues for the development of different policies and methods, as shown in the studies by Brabazon and MacCarthy (2006) and Calle and Gonzalez-R (2012). The literature review also shows that the degree of development and the study of these strategies is still insufficient, and there is no evidence of having been tested in real environments. Therefore, it is difficult to draw general conclusions, and it is not possible to extend them to other productive environments without the corresponding study.

Given the importance of the availability of a balanced inventory for the systems based on the FDP, the main objective of this work is to study the effect exerted by various sources of real-time information about the available products. Other issues studied in this work are the determination of the most suitable configuration for systems based on the FDP (regarding the factors included in this study) and the determination of the degree of influence of the considered policies of inventory control in the scope of this study.

The rest of the article is organised as follows: Section 2 presents a brief overview of the OFS directly related to this work. Section 3 contains the experimental design and the remaining details related to the methodology of experiments. In Section 4 the results are interpreted and discussed, pointing out relevant highlights useful for production managers. Finally, we conclude and remark on possible research directions.

2. OFS related research

In this section, we describe the most common aspects of the production systems included in this work. The production process consists of a manufacturing flow line (or pipeline) whose length corresponds to the WIP level. Finally, the finished products leave the pipeline and are stored in the FGI.

Each order fulfilment strategy serves customer orders in a particular manner, which implies a specific stage in the manufacturing value chain where a particular product is linked to a specific customer order (Brun and Zorzini, 2009), that is, the point in the system where the "push" (or forecast-driven) and "pull" (or demand-driven) elements of the supply chain meet. The location of this point is called Decoupling Point (DP). The following describes the main features of each of the strategies considered in this study, based on the combination of strategies (MTS and BTO).

2.1. System based on 2 fixed-DP

This system, called Conventional System by Brabazon and MacCarthy (2004b), is based partially on the MTS strategy, since the production is planned according to the demand forecast. The finished products are stored in the FGI, so it is possible to serve customer orders directly from the FGI when there is no stockout. In this case, there is a DP located at the FGI. Otherwise, when there is stockout of the requested variant, the system generates a new production order which is directly assigned to that customer. In this case, there is a second DP located at the beginning of the manufacturing line (Fig. 1).

Firstly, it should be noted that the waiting times of customers

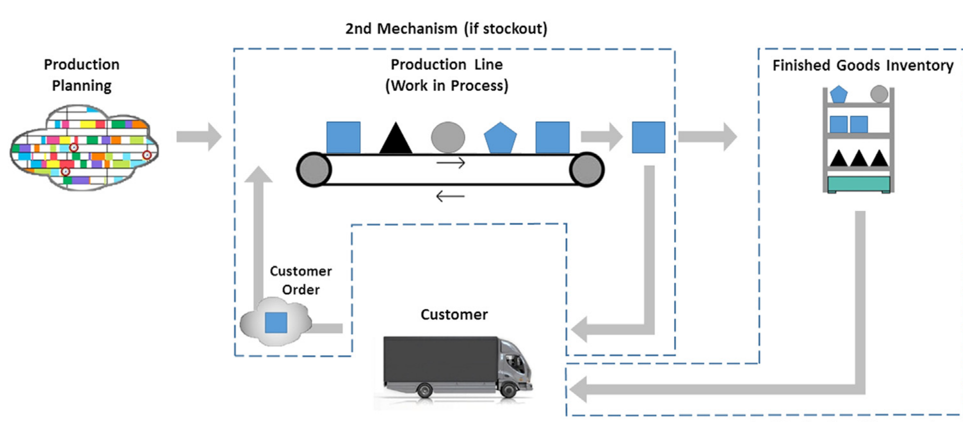

Fig. 1. System based on 2 fixed-DP.

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