European Journal of Operational Research 000 (2017) 1–16

Contents lists available at ScienceDirect

European Journal of Operational Research

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

Production, Manufacturing and Logistics

The automotive Order-to-Delivery process: How should it be configured for different markets?

Philip G Brabazon[a,*], Bart L MacCarthy[b]

[a] Centre for Operational Research and Logistics, Portsmouth Business School, University of Portsmouth, Richmond Building Portland Street, Portsmouth PO1 3DE, United Kingdom
[b] Operations Management and Information Systems Division, Nottingham University Business School, Nottingham NG8 1BB, United Kingdom

ARTICLE INFO

Article history:
Received 10 May 2016
Accepted 6 April 2017
Available online xxx

Keywords:
Supply chain management
Order fulfillment
Simulation
NOLH
CHAID

ABSTRACT

The Order-to-Delivery (OTD) process in the volume automotive sector is important for automakers, dealers and customers. It affects the customer's experience with regard to receiving a vehicle that matches their requested specification in a reasonable time and the costs of the automaker in serving the market. OTD processes share similarities across major volume automakers. They are substantial in scale with typically a very large number of vehicle variants and involve interactions between customers, dealers and the automaker. Additionally, automotive markets are heterogeneous. Some customers have little tolerance to compromising on specification and/or waiting for a vehicle whilst others are more tolerant on one or both attributes. This study examines how the OTD process should be configured for different markets. A representative simulation model is used with designed experiments and an innovative statistical analysis method to study the impact of nine OTD configuration factors in three different markets. The study shows that market attributes have a substantial bearing on the dominant modes of fulfillment, on customer-centric performance metrics and on automaker costs. The findings have strong implications for automakers regarding how they configure their OTD processes for different markets and whether they focus on upstream, pre-assembly factors and/or downstream post-assembly factors. This is the first study to use a comprehensive and detailed OTD process model, incorporating a wide range of configuration factors, and assess a full range of performance metrics in a designed simulation study.

1. Introduction

The automotive sector accounts for over 7% of world trade (WTO, 2014). Given its importance, it is not surprising that an extensive literature exists relating to its operations. Order-to-Delivery (OTD) is the process that begins with an auto retailer (a dealer) taking a customer order and ends with the customer receiving a vehicle. OTD processes have received less research attention, comparatively, than other areas of auto-industry operations such as new product development (Wynstra et al., 2010), the relationships and interactions with first tier suppliers (Lockström, Schadel, Harrison, Moser, & Malhotra, 2010), lean initiatives (Jayaram, Vickery, & Droge, 2008), and supply chain management (González-Benito, Lannelongue, & Alfaro-Tanco, 2013). In particular, modeling studies that seek to capture the OTD process in an integrated manner are scarce (Volling, Matzke, Grunewald, & Spengler, 2013). This is surprising given the effect of the OTD process on the customer's experience in purchasing a vehicle and the continuing industrial and media interest on issues such as inventory levels in distribution channels and at dealerships, waiting times experienced by customers, and purchase incentives offered by automakers (e.g. Bennett & Rogers, 2014; Kessler, 2015; Tobin, 2014; Wernle, 2014). The lack of modeling studies may be partly explained by the complexity of the OTD process and the modeling challenges that arise in seeking to capture its essential elements.

The review by González-Benito et al. (2013) on supply chain management in the automotive sector and the detailed review by Volling et al. (2013) specifically on planning models in the auto-industry, show a dearth of integrated OTD models reported in the literature. The literature review presented below corroborates this scarcity and highlights important gaps in understanding about how large-scale OTD processes should be configured. This study focuses on the OTD configuration problem. We use a detailed, industry-representative simulation model to investigate the impact of different OTD process configurations and different operating policies in three different market types. We undertake an extensive simulation study with a Near Orthogonal Latin Hypercube (NOLH) experimental design to determine the dominant factors affecting per-

* Corresponding author.
E-mail addresses: Philip.brabazon@port.ac.uk (P.G. Brabazon), bart.maccarthy@nottingham.ac.uk (B.L. MacCarthy).

http://dx.doi.org/10.1016/j.ejor.2017.04.017

formance in each market. A robust statistical interaction detector, CHAID (Chi-Square Automatic Interaction Detector) is used to analyze the results.

The work makes five contributions to the study and understanding of OTD processes in the volume automotive sector. Firstly, we provide the first reported study that investigates statistically a large number of factors influencing performance of the OTD processes using a large-scale simulation model with a realistic level of variety. Secondly, we examine and compare OTD behavior and performance for different market contexts, characterized by diversity in customer characteristics within and between markets. The study finds the three markets have different dominant modes of fulfillment, have different marginal costs of fulfillment, and different customer service metrics with respect to the waiting times and the degree of compromise experienced by customers. Thirdly, the study identifies the dominant factors affecting OTD performance and behavior with respect to each market. Consequently, different markets need different OTD process configurations. Fourthly, the study highlights the tension between OTD configurations that minimize cost and those that are best for the customer experience, which makes it challenging for automakers to decide an appropriate configuration. Fifthly, the study provides guidance for automakers in how to configure their OTD processes for different markets.

We organize the paper as follows. Section 2 reviews current understanding of OTD processes in order to identify gaps and define the research objective. Section 3 describes the simulation model and its validation, the design of experiments and the statistical analysis procedures used. Section 4 presents the results, followed in Section 5 by a discussion of findings, research contributions, and their managerial implications. Section 6 concludes with a summary, noting limitations of the study and the potential for similar studies in other complex fulfillment scenarios.

2. Literature review

The literature review begins by defining the term 'Order-to-Delivery' (OTD) process as typically used in the volume automotive sector. This first section also identifies similarities and differences in how the OTD process is implemented by automakers. The second section identifies major challenges faced by automakers in operating their OTD processes. The third section reviews previous OTD modeling studies and analyses and compares them in detail. The gaps in the existing studies are identified and the research objective for this study is set.

2.1. Defining the Order-to-Delivery process

'Order-to-Delivery' is a common term in the automotive sector (e.g. Holweg, 2003; Meyr, 2004; Zhang, Chen, & Ma, 2007) but 'order fulfillment' is also used (e.g. Staeblein & Aoki, 2015) and other terms arise, such as 'Market Flexible Customizing System' (Tomino, Park, Hong, & Roh, 2009). The objective of the Order-to-Delivery (OTD) process is to provide each customer with the vehicle of his or her chosen specification. A richer explanation, based on Stauntner (2001, cited in Meyr, 2004), highlights the aims of the process – OTD should achieve short delivery times for customer-specified vehicles, be reliable in keeping to promised delivery dates, and allow customers to change their specification until the last moment.

Sources including Holweg and Jones (2001, cited in Zhang et al., 2007), Aoki, Staeblein, and Tomino (2014), Tomino et al. (2009), Staeblein and Aoki (2015) describe the constituents of the contemporary OTD process in different levels of detail, but they are generally consistent. The most detailed is the first source where OTD is described as having seven stages – order entry, order bank, order scheduling, order sequencing, manufacturing, distribution to distribution center (DC) and transportation from DC to dealer.

Researchers report that European and Japanese automakers have similar OTD processes (Staeblein & Aoki 2015; Aoki et al., 2014; Lim, Alpan, & Penz, 2014; Tomino et al., 2009). Most customers purchase vehicles through dealers, and the physical flow from suppliers to assembly plant and to customers, which may be via a vehicle holding compound (VHC), is similar. These automakers allow orders in the production plan that are destined for stock to be allocated to customers. They also allow the specification of such vehicles in the production plan to be amended for customers, unless they have reached a point in time when their specifications cannot be altered because of production constraints, i.e. the planned vehicle specification is 'frozen' close to production (Lim et al., 2014; Aoki et al., 2014; Brabazon, MacCarthy, Woodcock, & Hawkins, 2010; Tomino et al., 2009). There are limits to this flexibility, as noted by Lim et al. (2014) who state that Renault constrain the cumulative amendments permitted in the production plan and Toyota restrict changes to +/−10% from the plan agreed at 10 days prior to assembly.

There are differences between automakers. Many, but not all, allow dealers to fulfill a customer with an unsold vehicle or replenishment order in the pipeline taken from another dealer (Williams & Bozon, 2006). Another potentially significant difference relates to the latest opportunity that is offered to dealers to amend a planned vehicle before its specification is frozen ahead of production. German automakers freeze the specification 7 days before production (Staeblein & Aoki, 2015). At Renault it is also 7 days for most assembly plants but for those with distant suppliers it is 4 weeks (Lim et al., 2014). For Toyota, Mitsubishi and Nissan it is 3, 5, and 4 to 6 days, respectively (Tomino et al., 2009).

2.2. Challenges in the design and management of the OTD process

Evidence and insights about customer expectations and how well automakers are meeting them is relatively scarce in the research literature. A survey in Germany concluded that the order lead time desired by customers is normally distributed with a mean of 4 to 6 weeks (Stauntner, 2001 cited in Meyr, 2004). In contrast, according to Elias (2002) only 6% of UK car buyers were happy to wait over 4 weeks, with 1 to 2 weeks being the most desired lead time. Most US customers are not prepared to wait beyond 3 weeks as found in a survey by Gartner (cited by Holweg & Pil, 2004). In respect of compromising on vehicle specification, Bardakci and Whitelock (2004) compared the attitude of Turkish and UK customers and found differences between these markets and within each market. Taken together, the conclusion is that customer attitudes toward lead time and compromise on specification differ between customers within a national market and between markets.

Evidence shows that automakers are not matching customer expectations on lead time. Aoki et al. (2014) present data for different German and Japanese makes and models and they vary greatly, from 2 to over 30 weeks. An independent website gathering data from UK dealers reported the average lead time for a factory supplied new car (as opposed to a vehicle from finished stock) in April 2016 was 13 weeks, with the quickest being the Toyota Auris at 2 weeks, and the longest being the Mercedes GL at 52 weeks (New Car Delivery Times, 2016).

There is very little data on customer compromise in respect of expectations or experience. Elias (2002) reports almost a quarter of UK buyers compromised on at least one feature. Furthermore, nearly half of customers who compromised received compensation in the form of a price discount, an upgrade, a better finance arrangement or a better price for a traded-in vehicle. The scale of compensation is not reported, but it is clear that compromise has a cost to the automaker and/or dealer. Although not in the specific context of the automotive market, Franke et al. (2010) provide an