Analyzing the Effect of Delivery Time Differentiation on Supply Chain Performance in the Automotive Industry

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Delivery time differentiation is a supply chain concept that has been implemented in various industries, but not yet in the automotive industry. In the automotive industry, segmentation of customers with respect to delivery times is still in its infancy and the main differentiation is between built-to-stock and built-to-order cars. In Europe, for instance, 30% of the cars are sold from stock and 70% are built to order. With the current processes customers must decide between buying a pre-configured car from stock with immediate delivery and ordering a customized car with a substantial delivery time of several months. For various reasons, customers value fast delivery.

Customized cars with short delivery times could be an attractive market segment for automotive companies, because customers of that segment are likely to have a high willingness-to-pay, but this segment is currently not served by any major manufacturer. BMW Group, for instance, has considered offering an express order option, where express orders bypass standard orders in the supply chain processes to achieve short delivery times. While BMW's management is aware that express orders distort planning processes, increase operations cost, and increase the delivery times of standard orders, it could not quantify the effects and thus did not feel comfortable deciding about the implementation of express orders. To understand the consequences better we analysed the relevant supply chain processes at BMW Group.

To analyse the effect of introducing express orders on expected delivery times and expected cost, we use queuing theory and derive expressions for the transient behaviour of a discrete time batch

queue. To analyse the effect on component demand, we derive the component demand distribution. Generally, express orders increase the uncertainty of component demand and additional inventory is required to achieve the same service level with express orders than without. We show how the optimal inventory level and expected cost can be determined and how they are affected by the express orders.

Our analyses indicate that express orders affect many supply chain processes, but that the effect on cost is marginal at most processes. For instance, prioritizing orders in the scheduling process requires some adaptation of the scheduling software, but can otherwise be implemented at low cost. The cost of the actual assembly process production processes is hardly affected by the introduction of express orders, as long as they do not affect the orders within the freezing period (orders one-week-ahead of production that must not be altered by dealers or customers). Our analyses shows that the two main effects that express orders have on supply chain performance are increases in delivery times of standard orders and increases in the uncertainty of component demand, which increases component inventory levels and the related costs. Our results indicate that express orders can be an attractive option for BMW and other automotive companies. If the fraction of express orders stays at a reasonable level, express orders can be delivered within about two weeks compared to delivery times of several months for standard orders.

Our research has important managerial implications. It provides an approach for analysing the effect of express orders on expected delivery times and cost. For a specific company, we quantify the effect and it is reasonable to assume that the effect is similar at other automotive manufacturers, because most use similar processes. Our model can also be used to analyse highly

utilized build-to-order processes outside the automotive industry. The approach would be similar to the one that we present, but the magnitude of the effects would most likely be different.

We contribute to the literature on *supply chain segmentation*, *advance demand information*, and *batch queues*. The *supply chain segmentation* literature focuses on uncapacitated systems and systems where capacity is not necessarily fully utilized. In the automotive industry, however, demand is managed, such that production capacity is usually fully utilized during a shift. We contribute to the supply chain segmentation literature by analysing a model with high product heterogeneity and fully utilized production processes. The literature on *advanced demand information* focuses on analyzing the value of having better demand information available for decision making. In our model, express orders replace standard orders, which have component demands that have already been communicated to suppliers, thus reducing the quality of ADI. We contribute to a recent stream of ADI literature, which analyses the impact of imperfect ADI on cost. The early work on *batch queues* analyses the queue lengths distributions and waiting times of continuous time queues, while more recent work also derives the distribution and moments of queue lengths and waiting times for discrete time queues. For our analyses, we require the transient output distribution of a discrete time, batch arrival, batch service queue. The distribution has been derived for individual arrivals and single server queues in continuous time but not for the discrete time queue that we require for our analysis and we provide the results in this paper.