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# Part logistics in the automotive industry: Decision problems, literature review and research agenda

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ABSTRACT

With the ongoing trend of mass-customization and an increasing product variety, just-in-time part logistics more and more becomes one of the greatest challenges in today's automobile production. Thousands of parts and suppliers, a multitude of different equipments, and hundreds of logistics workers need to be coordinated, so that the final assembly lines never run out of parts. This paper describes the elementary process steps of part logistics in the automotive industry starting with the initial call order to the return of empty part containers. In addition to a detailed process description, important decision problems are specified, existing literature is surveyed, and open research challenges are identified.



## 1. Introduction

Whenever a stock-out at an assembly line of an automobile manufacturer occurs, one of the following reactions is required:

- If the shortfall is detected before having finally released a car body requiring one of the missing parts into final assembly, the workpiece may be retained from central storage and an alternative car is released into the free production slot. This, however, causes nervousness in production and logistics. For instance, parts already being sorted according to the initially planned production sequence need to be reshuffled and a delayed car body may lead to a late delivery and a dissatisfied customer.
- Alternatively, an express delivery can be initiated provided that the stock-out is anticipated early enough. For example, if a truck is delayed on its way to the factory, some additional (fast) vehicle or even a helicopter can be called in to quickly fetch the relevant parts. If the parts have already arrived at the factory but not at the consuming station, an emergency delivery is typically executed by bicycle or some other in-house vehicle.
- Another possible reaction is to proceed with assembly as though nothing had happened and simply skip the missing part. Once available, the left-out part needs to be retrofitted in the rework area by highly trained (and therefore well paid) assembly workers. These workers may have to first partially disassemble (and later reassemble) the car in order to mount the missing part.
- In the worst case, if indispensable parts are missing, an assembly line has to be stopped. This results in hundreds of assembly workers being idle and every 60 to 90 seconds, which is the typical range of cycle times in automobile assembly, the profit of one car is lost.

All aforementioned reactions to missing parts cause high penalty costs. Hence, strict requirements with regard to reliable operations are imposed on part logistics. However, in today's automotive production some recent trends further increase the relevance of part logistics (Battini, Boysen, & Emde, 2013):

- Firstly, value creation has been withdrawn from the main line. According to Dudenhoefer (2006) an average compact car requires merely 15 hours of assembly time at its original equipment manufacturer (OEM). A study by Krcal (2007) indicates that over the last decade, average production depth in automobile industry declined from about 43 percent to 25–35 percent. In addition to the widespread trend of concentrating on core competencies, this way salary differences between an OEM and its suppliers can be exploited.
- To satisfy individual customer needs, today's car buyers can customize their cars from a wide range of individual options (e.g., cruise control yes/no) resulting in billions of different (theoretically possible) car models (see Pil & Holweg, 2004, for detailed figures). Clearly, an increasing catalogue of options increases the variety of parts to be handled. Furthermore, in particular luxury

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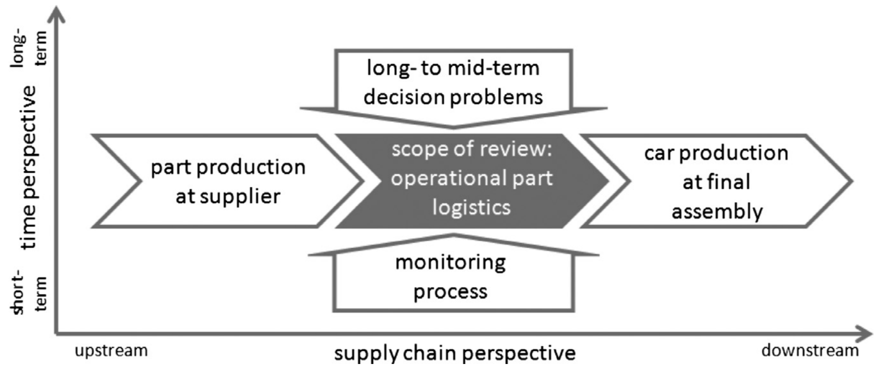


**Fig. 1.** Scope of the review.

car manufactures offer their customers the chance to update the configuration until a few days before production starts, e.g. at BMW a car's configuration can be changed until seven days before production. This marketing tool has proven to be successful in generating higher revenues per car. From a logistics point of view, however, this sales instrument increases uncertainties about the parts needed and, therefore, considerably reduces planning cycles of part logistics.

- To quickly react on varying demands over time, nowadays, most OEMs assemble not only a single but multiple car models on the same assembly line, i.e. a mixed model line. The factory in Bratislava (Slovakia) of Volkswagen, for example, assembles multiple models of different brands (Touareg by Volkswagen, Q7 by AUDI, and Cayenne by Porsche) in facultative sequence on the same line.
- Inspired by the Toyota Production System, Just-in-Time (JIT) became a fundamental concept for OEMs all over the world. Delivering parts just when they are needed reduces inventories at the OEM. However, the logistics effort at the OEM can be further reduced if parts are delivered Just-in-Sequence (JIS). JIS means that parts are pre-sorted into bins by the supplier, so that assembly workers can withdraw these parts in the right order just as defined by the production sequence. Both concepts, JIS and JIT, shorten delivery cycles and increase the reliance on well-planned and reliable logistics operations.

All these trends lead to an increasing number of parts delivered from a wide range of suppliers in short planning and delivery cycles. At the medium-sized automobile plant of BMW in Dingolfing, for example, more than 13,000 containers delivered by about 600 suppliers on more than 400 trucks need to be processed every day (Battini et al., 2013).

Starting with a call order reaching a supplier, parts are transported via external logistics to the OEM. Once arrived, in-house logistics takes over until parts are delivered to the line. Finally, empty bins and containers need to be returned to suppliers in order to be refilled with parts, which is the task of reverse logistics. This paper reviews the process of part logistics in the automotive industry from an operational research perspective.

For this purpose, the remainder of the paper is organized as follows. Section 2 defines the scope of this review by describing the elementary process steps of part logistics in the automotive industry. The process is broken down into three subprocesses, namely external, in-house, and return logistics, and a separate section is dedicated to each subprocess. Within each of these three sections, the basic steps of each subprocess are described and their elementary decision problems are defined. Then, the scientific literature providing solution procedures and decision support tools for these problems is reviewed and future research needs are identified. Finally, Section 6 concludes the paper.

## 2. The part logistics process—Scope of the review

This paper deals with logistics operations, i.e., receiving, storing, packing, transporting, returning goods and exchanging associated information within an automotive supply chain. The scope of our review starts upstream with the call order submitted to a supplier. Downstream, we have the assembly process of the final assembly line where parts are finally consumed. Therefore, the last process steps treated are the line side presentation of parts in appropriate racks and bins prior to final assembly and the management of returning empty bins. In between these two interfaces this review covers all process steps required for external logistics from (supplier) plant to (OEM) plant (Section 3), for internal logistics from receiving store to final assembly (Section 4), and for reverse logistics of returning empty bins (Section 5).

In addition to the functional restriction of excluding all manufacturing activities within the automotive supply chain, a temporal delimitation is required. Our survey is restricted to the operational planning process. On the one hand, this excludes all strategic decision problems, such as all problems concerning the location of warehouses and plants (see, e.g., Klose & Drexl, 2005), layout of facilities (see, e.g., Drira, Pierreval, & Hajri-Gabouj, 2007), supplier selection (see, e.g., Choi & Hartley, 1996; Cusumano & Takeishi, 1991), as well as investment decisions in machinery, equipment and personnel. Also real-time monitoring of logistics execution is excluded from our review. Often external (mostly truck deliveries) and internal logistics are monitored by the global positioning system (GPS) or some manufacturing execution system (MES) system, respectively. Once a potential stock-out is detected, one of the aforementioned reactions, i.e., delaying a car, express delivery, proceeding with assembly, or line stoppage, needs be initiated. In conclusion, Fig. 1 schematically depicts the scope of this paper.

The core process steps of operational part logistics are shown in Fig. 2, which can be subdivided into the (traditional) forward chain and the reverse chain. The former covers the way of parts from the supplier to final assembly and consists of the two subprocesses: external logistics and in-house logistics.

External logistics entails all activities required to supply parts from an external or internal supplier's facility to the OEM's plant, whereby especially two process steps are essential: JIT part supply requires long-term supplier relationships and frame agreements. Within such a contractual framework short-term *call orders* are submitted on a regular basis. These orders include the demand of the final assembly for a specific part and time horizon and, therefore, initiate the part logistics process. Then, these items are produced JIT at the respective part supplier or pre-produced units are taken from a warehouse and *external transport* is initiated to ship the parts from the supplier's plant to the OEM's facility typically by truck.

Afterward in-house logistics takes over and all steps from receiving parts up to arranging them in appropriate racks and bins at the