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A comparison of different container sorting systems in modern rail-rail transshipment yards

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A B S T R A C T

Rail-rail transshipment yards act as central hub nodes within a railway network and enable a rapid consolidation of containers between different freight trains. To avoid an excessive movement of gantry cranes when transferring a container from one train to another, modern yards apply sorting systems where shuttle cars move containers horizontally along the spread of the yard. This paper compares four elementary sorting systems. Specifically, we compare rubber-tired and rail-mounted shuttles and differentiate whether a pure shuttle system or a lift & shuttle system is applied. In pure shuttle systems, a shuttle receives a container from a crane and transports it towards the destination crane, where it serves as a storage device until being unloaded. A lift & shuttle system applies shuttles with an integrated lifting platform, so that they are able to autonomously store and receive containers from a separate storage rack. Both alternatives exist in rubber-tired and rail-mounted versions. As the shuttles are the main driver of the investment costs, we compare the required fleet size for timely supplying given gantry crane schedules within all four systems. For this purpose, we derive suited scheduling procedures. This way, decision support for yard managers having to identify a suited sorting system and to layout a new terminal is provided.

1. Introduction

Ever since 1955 when Delta Airlines pioneered the hub-and-spoke system by introducing its central Atlanta hub (Delta Air Lines, 2013), intermediate hub nodes have played a crucial role not only for the airline industry but also for alternative transportation devices. A hub-based consolidation of passengers and shipments in order to concentrate them along central transport relations is, for instance, also enabled by cross docks for a road based transportation (e.g., see Boysen and Fliedner, 2010). Another example are central ports where containers are exchanged between huge inter-continental container vessels and smaller feeder ships (e.g., see Zhen et al., 2011). For the railway network such a consolidation is equally essential, because otherwise only point-to-point transport between large urban areas that generate cargo volumes large enough to load full trains to capacity shows profitable (Trip and Bontekoning, 2002).

However, existing rail terminals are often ill-suited for a rapid transshipment of containers between freight trains. On the one hand, traditional shunting yards (e.g., see Boysen et al., 2012) require a time-consuming disassembly of inbound trains before they allow for a tedious new formation of trains by moving railcars over a shunting hill (Bontekoning and Priemus,

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2004). Intermodal transshipment yards (e.g., see Boysen et al., 2013), on the other hand, are originally designed to exchange containers between freight trains and trucks by huge gantry cranes spanning rail tracks and truck lanes. If intermodal yards are beyond that also applied as hub nodes for transferring containers between different freight trains, then the resulting rail-rail container moves require long horizontal crane movements along the spread of the yard. This, in turn, leads to excessive crane interference on the cranes' shared track and, thus, prolonged train processing times.

To accelerate rail-rail container moves modern transshipment yards (also denoted as third-generation terminals, Boysen et al., 2013) apply an additional sorting system for moving containers horizontally along the spread of the yard. In a sorting system, a shuttle car moves to the horizontal position where a container is located on its incoming train, the container is loaded onto the shuttle by a gantry crane, and the shuttle moves towards the horizontal target position where the container is finally stacked on its dedicated position on an outbound train by another gantry crane. This way, cranes are unburdened from horizontal movements, so that obstructions among them are avoided and container processing is accelerated. This, in turn, makes the sorting system to the core element of the transshipment process and efficient shuttle operations to an important enabler of a rapid consolidation in rail-rail transshipment yards.

1.1. Sorting systems in modern rail-rail transshipment yards

The completion of such a modern rail-rail transshipment yard is currently planned for 2019 in Hannover-Lehrte (Germany). After a tedious planning phase over more than 16 years, which is documented by Alicke (2002) and Rotter (2004), the budget for this terminal has now been finally released and construction work has started. This terminal – also denoted as the *Megahub* – will consist of six rail tracks for processing freight trains by three parallel gantry cranes, which also span truck lanes (for parking and driving), an intermediate storage area for ground storage of containers, and a sorting system as is depicted in Fig. 1.

Preliminary simulation studies during the planning phase have identified a pure shuttle system consisting of 12 rail-mounted shuttle cars being a suited choice for the Megahub (Rotter, 2004). Currently rather a sorting system based on automated guide vehicles (AGVs) is preferred (Deutsche Bahn, 2016). In both systems, however, a shuttle is occupied by a container during the complete time span between the loading and unloading process of the cranes, so that a large number of shuttles is required. A separate container storage lane and shuttles with integrated lifting devices provided by a lift & shuttle system release shuttles from the storage function and therefore promise to get by with fewer shuttles. Another important distinction is whether rail-mounted shuttles or rubber-tired vehicles are applied. Among the rubber-tired vehicles there also exist pure shuttle systems, i.e., AGVs like they are commonly applied in large container ports (Steenken et al., 2004), and lift & shuttle systems (denoted as lift AGVs or ALVs, Vis and Harika, 2004). Fig. 2 schematically depicts the four resulting alternative sorter solutions. This paper aims at a general comparison of the four alternatives and their performance in rail-rail transshipment yards. All alternative systems are briefly characterized in the following (see also Kreutzberger and Konings, 2016):

- *A1:* In a *rail-mounted pure shuttle system*, a shuttle, i.e., some self-propelled railcar, is loaded with a container by a gantry crane (on a waiting bay next to the container's railcar on the inbound train), moves along a mono-directional, closed-loop rail track towards a waiting bay close to the container's destination, and waits there until another crane finally stacks the box onto its outbound train. In the initial plan for the Megahub, shuttles are designed to have rotatable wheels, which they turn by 90° when moving into a bay (Rotter, 2004).

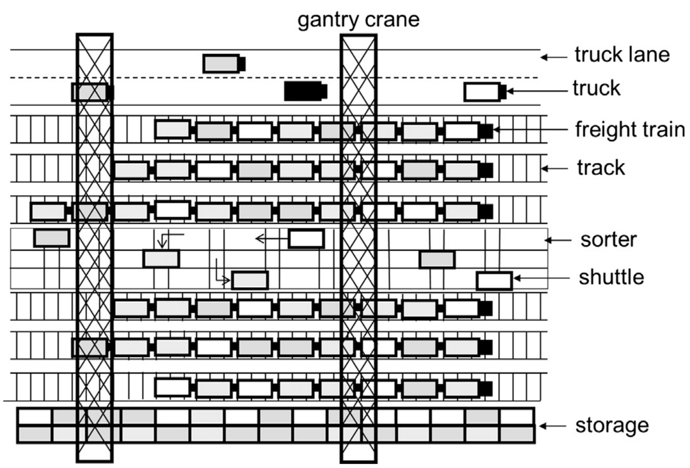

Fig. 1. Schematic layout of a modern rail-rail transshipment yard.