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Synchromodal hinterland freight transport: Model study for the port of Rotterdam

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ABSTRACT

This paper develops a model that enables comparative analysis of intermodal and synchromodal operations from economic, societal, and environmental perspectives. The model captures relevant (day-to-day and within-day) dynamics in freight transport demand and supply, flexible multimodal routing with transfers and transhipments. The capacitated schedule-based assignment algorithm operating specifically at path level allows strategic modelling and evaluation accounting for the freight transport system at operational level. The Rotterdam hinterland container transport case study shows that synchromodal system is likely to improve transport service level, capacity utilization, and modal shift, but not to reduce delivery costs.

1. Introduction

The European freight transport sector faces the challenge to catalyse economic growth by facilitating the increase in freight transport demand while retaining a sustainable transport system (CEC, 2009). To this end, European hinterland freight transport policy over the past two decades has aimed at modal shift towards sustainable modes such as rail, inland waterway, and sea transport (EC, 2001). In this context, intermodal transport is promoted as a promising solution. Intermodal freight transport is the term used to describe the movement of goods in one and the same loading unit or vehicle by successively using various modes of transport (road, rail, water) without any handling of the goods themselves during transhipment between modes (European Conference of Ministers of Transport, 1993). These efforts to promote modal shift and intermodal transport entail: subsidizing intermodal freight transport (Transport Research Knowledge Centre, 2009), pricing road freight transport (CEC, 2006), liberalizing the freight transport market (CEC, 2006), and improving freight transport service quality (CEC, 2007). Despite these efforts, the shift away from road transport has been limited, mainly because intermodal transport is less agile in reacting to the dynamics in the freight transport system. These dynamics include the varying composition of the freight in the transport demand, and the time-varying capacities in the freight transport supply with respect to the physical infrastructure network and facilities, the service network, and the fleet and crew. The constraints caused by extra handling and associated requirements on facilities and equipment result in intermodal transport typically providing less flexibility, lower reliability, extra transhipment costs, longer delivery times, and less robustness.

Recognition of these disadvantages led to an additional action plan (CEC, 2007), where better utilization of infrastructure, better integration of the modes, costs reduction, and quality criteria are set forth as the new objectives in order to improve competitiveness of intermodal transport. A specific goal was set in the White Paper on Transport 2011 (EC, 2011) as "growing transport and supporting mobility while reaching the 60% emission reduction target". At the same time, new transport patterns are expected to emerge where larger volumes of freight are carried jointly to their destination by the most efficient (combination of) modes.

The Netherlands shares this situation, and is confronted by an extra challenge related to the large volumes of freight generated in the port of Rotterdam, to be transported to a large number of destinations in the hinterland. Many of these destinations are within a transport distance of 300 km, which is identified as a distance not preferable for intermodal transport (EC, 2011). At these shorter distances, it is difficult for intermodal transport to compete with unimodal road transport. The main reason is that the costs saved from using rail or inland waterway transport often cannot compensate the extra costs incurred in the intermodal handling in terms of both direct monetary costs and time. This difficulty is in addition to the earlier mentioned disadvantages of intermodal

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transport. In response to these circumstances, an emerging emphasis is now given to the design of services and the cooperation of multiple service providers at operational level aimed at synchronization of intermodal transport services.

A synchromodal freight transport system is emerging and developing fast as a new concept of freight transport operations. It is now on the agenda of the Dutch government and sector institutes, including the Dutch Top Sector Logistics (Topteam Logistiek, 2011). Although the term "synchronization" has been used before in literature concerning freight transport, for example indicating a seamless supply chain (Rodrigue, 1999) or an integrated information-material flow (Baalsrud Hauge et al., 2011), the concept of "synchromodal freight transport" is different. As proposed by the Dutch Institute for Advanced Logistics (Dinalog) synchromodal transport entails that "A shipper agrees with a service operator on the delivery of products at specified costs, quality, and sustainability but gives the service operator the freedom to decide on how to deliver according to these specifications" (Dinalog, 2015).

The concept of synchromodal transport has gained so much interest due to its potential of benefiting from the advantages of intermodal transport without sacrificing the quality of service. Different from the development of intermodal transport, which emphasises the utilization of rail or waterborne transport capacity in order to benefit from scale economies and to achieve lower transport costs and emissions, instead synchromodal transport aims at the integration and cooperation among transport services and modes, in order to give the service operators more possibilities to provide better transport alternatives to the shippers by utilising multiple services of multiple modes.

The objective of our research is to explore the potential impact of synchromodal freight transport for port-hinterland distribution comparing to the traditional intermodal freight transport. That is, we analyse what economic, societal, and environmental effects could be expected if the current intermodal system would be replaced by a synchromodal system. By an extensive review of the relevant literature, we conclude that no study yet reports a quantitative analysis of potential effects of synchromodal freight transport, and existing evaluation models are not sufficient to conduct this analysis. Therefore, in this paper, we develop a capacitated schedule-based service network design model with time-varying demand and supply that operates specifically at path level. This approach enables strategic decision-making based on system performance evaluation from governmental perspective, while capturing the synchromodal freight transport concept that pushes a number of operational decisions from shippers to service operators. We implement the model to the container transport from port of Rotterdam to its hinterland along the Rhine corridor, and analyse the effects of a synchromodal system compared to an intermodal system. Our contributions are our modelling approach that enables quantifying the impacts of synchromodal freight transport, and the Rotterdam application that analyses these impacts.

The next section discusses the concept of synchromodal transport in more detail and in relation to existing transport planning studies and models. In Section 3 we present our model that embeds two flow assignment methods representing the intermodal and synchromodal system, and in Section 4 calibrate and apply this model to quantitatively analyse the hinterland container transport of the port of Rotterdam.

2. Problem statement and existing studies on intermodal and synchromodal freight transport planning

In the most constrained system, a service operator may provide possible service paths to shippers, where paths are characterized by origin, destination, departure time and vehicle, while a shipper decides to book a specific slot on a predefined service path. We refer to this case as *fixed booking*. This system can be observed in nowadays intermodal transport. Here service operators cannot optimize transport decisions in response to any real-time information on prevailing available capacity of their service network. And this information is not available to the shipper. Contrarily, synchromodal transport aims at more transport decisions being made by service operators thus enabling transport decisions to be made closer to real-time. Cases can be distinguished depending on the specific decision(s) that is transferred from shipper to service operator. For example, another system, which represents the current practice, we refer to as *open service path booking*. In this case the shipper decides the service line to use and a specific delivery time, but leaves the departure time for the service operator to decide. In case the service operator decides the route, terminal of origin, terminal of destination, service line, vehicle, and departure time, we refer to this case as *open route booking*. The service operator has the opportunity of optimizing their routing, fleet and crew capacity, in pre-haulage, main-haulage, and end-haulage, thereby accounting for the handling capacity at competitive terminals. In case the shipper only specifies the delivery time, while the service operator determines all transport decisions and thus can respond to the latest information on prevailing transport demand and supply. We refer to this as *Open mode booking* which enables optimization of routing, fleet and crew capacity, in pre-haulage, main-haulage, and end-haulage, thereby accounting for the handling capacity at competitive terminals. Of interest for this study is what we refer to as *open service path booking* (representing an intermodal system) and *open mode booking* (representing a synchromodal system).

A synchromodal system in this form of *open mode booking* potentially exploits the reduced costs and emissions of intermodal transport as well as the service quality of direct road transport. Thus it is postulated to reduce delivery times, provide better utilization of the capacity of each mode, and allow for buffering effects between the alternative modes yielding a more flexible, reliable, and robust transport system. However, to the best of our knowledge, no study yet reports a quantitative analysis of the economic, societal, and environmental effects of synchromodal freight transport as compared to those of intermodal transport.

Macharis and Bontekoning (2004) and Caris et al. (2008) provide reviews particularly focusing on intermodal transport operations. They conclude that most studies focus on the strategic level, often pertaining to infrastructure network design and terminal allocation, where model-based approaches typically describe the flow assignment as a function of static and aggregated attributes. Reviews of these planning problems and models are given by Tavasszy et al. (2012); de Jong et al. (2013); Caris et al. (2013); Nuzzolo et al. (2013), and SteadieSeifi et al. (2014). Nuzzolo et al. (2013) conclude that among models developed in the last two decades only few transport forecast models are able to deal with large-scale problems while accounting for micro-mechanisms in the underlying demand. SteadieSeifi et al. (2014) mention that synchromodal transport is "the next step after intermodal and co-modal transportation", however, "no operations research literature had been found where synchromodal is used".

While reviewing the existing methods and models, we observe that the network evaluation tools used in the field of freight transport modelling are originally constructed for the purposes of (long-term) strategic infrastructure network planning and (medium-term) tactical service network planning, and hence are static in nature (Bontekoning et al., 2004; Caris et al., 2008). However, there are dynamics in both demand and supply of the transport system working at much finer than annual scale, which may influence the system performance.

The dynamics in demand are predominantly determined by the unreliable schedules of sea-going vessels, the varying composition of the freight, and variations in their characteristics (and hence requirements). In the general intermodal service network design frameworks (see for example Crainic and Rousseau (1986); Farvolden et al. (1993)), demand is defined by origin terminal, destination terminal, and commodity type. Bauer et al. (2010) extend the classical frameworks, where an origin is defined as a given terminal at a given point in time over the planning horizon. Yaman (2009) emphasizes the