Synchromodal transport with disruptions

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This research is part of the cSBO Digital twIn for SynchromodAl Transport (DISpATch) project. Synchromodal transport is the transport of freight with multiple modes in a synchronised manner between companies in the supply chain. Given the real-time dynamics and flexible nature of synchromodal transport, different actors and transport modalities need to work together and adapt according to unexpected events as well as contextual information that affects transport processes. The main project objective is to facilitate synchromodal transport by identifying and addressing these uncertainties. This will be done by developing a digital twin platform. A digital twin is a virtual environment that mirrors the real physical system (a physical twin) and its processes by updating its virtual real-time status from various sources of information. Different actions can be simulated when uncertain events take place to obtain the best decisions in the physical world.

This research focusses on continental synchromodal transport. Road freight transport is currently heavily used despite higher operating costs than rail and barge modes. Besides economic considerations, road transport leads to externalities such as congestion, road degradation and high CO2 emissions. These problems are expected to deteriorate as transport demand continues to increase. One of the main issues preventing a modal shift is the lower flexibility of other transport modes. Networks are subject to uncertainties and, when faced with a disruptive event, deviations from the initial plan may be required. In this case, trucks can easily take another route whereas other modes cannot. As such, it might be beneficial to keep spare truck capacity when switching freight to other transport modes.

The objective of this research is to determine the optimal distribution of truck, train and barge capacities for carriers in a synchromodal setting. The first step in this research is to perform a literature review on uncertainties in synchromodal transport networks. The most relevant characteristics are the types of uncertainties and proposed decision rules, and how these are included in the model formulations and solution methods. Studied uncertainties are variations in demand, travel time and capacity reductions. Because network planning decisions and managing uncertainty should not be done separately, this study will consider uncertainty at different levels. On the strategic and tactical levels, expected effects of uncertainty are mitigated by reducing the likelihood or impact of disruptions. Resolving disruptions that make it through is done at the operational level.

Facility location problems (FLPs) are the most commonly addressed in strategic planning. Against uncertainty, objectives other than minimising expected costs are considered such as minimising losses of the worst case scenario. For both travel time uncertainty and facility failures, having a central facility and locating facilities more closely together results in lower costs since demand can be absorbed by nearby facilities [1, 2]. Because FLPs have a high computational complexity, heuristics are preferred over exact solution methods. Constructive heuristics followed by an improvement heuristic were shown to yield good results with low run times.

Tactical planning problems are predominantly on network flow planning (NFP) or service network design (SND) [3]. In SND problems, offered services and schedules are chosen to route flows. NFP assigns flows to routes for a given service network. Considering uncertainty leads to lower costs and higher service levels on average. However, adding reliability measures to the objective leads to a higher share of truck transport. In SND problems with stochastic travel times, optimal schedules are spread out more so that tolerances for late arrivals are higher.

Recovery actions on an operational level comprise rescheduling, rerouting and outsourcing. Combining these decisions with tactical planning problems in two-stage models was shown to increase resilience and reduce expected costs [4]. In the first stage, stochastic SND problems are solved by minimising expected costs. Recovery actions are determined in the second stage, which takes place once uncertainty has materialised. Evidently, incorporating more recovery actions can only improve the optimal solution, but this comes at the cost of higher computational complexity [5]. Better solutions may be obtained faster when fewer types of recovery actions are considered, which is especially significant for short-term decisions where longer times can render the model unviable.

In the second step, a real-life case of a logistics service provider considering a modal switch from road to rail transport is investigated. Because trains are booked in advance, major concerns are the amount of rail capacity that must be booked and the remaining truck capacity needed to deal with disruptions. To address these issues, a model will be developed for a single transport corridor that includes short-term recovery actions.

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