

Optimization-based integration platform for Synchromodal Logistics

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## Abstract

Synchromodal Logistics is a recent paradigm aiming to improve the efficiency, reliability, flexibility, and sustainability of the services used for freight shipping. Crucial factors for achieving these goals are the coordination and cooperation of stakeholders and the synchronization of operations using innovative technology solutions. The thesis starts with an overview of the current status of logistics and supply chain management, providing a deep analysis of the paradigm of synchromodality. We present the peculiarities, critical success factors, and enabling technologies of synchromodality, discussing the relevant literature and case studies.

Then, we propose a new paradigm to manage operations called *smart steaming* to provide a more efficient and sustainable strategy to implement services within a synchromodal logistics network. The main idea behind this new concept is to exploit a comprehensive view of a logistics network to coordinate vehicles by adjusting their travel speed in real-time to react to unexpected events such as port congestions, traffic, or bad sea conditions. We discuss the literature related to relevant topics such as slow steaming, fuel consumption models, and speed optimization problems. Moreover, we describe how smart steaming can be used to deal with environmental policies and the current operational limitations on its implementation.

The complexity of implementing synchromodality and smart steaming requires complex technology solutions. Developing an optimization-based integration platform can be one way to achieve it by integrating the enabling technologies and offering specific tools for the various stakeholders involved in freight logistics. We developed a prototype of an optimization-based integration platform for Synchromodal Logistics within the Horizon 2020 SYNCHRO-NET project. Different modules using different enabling technologies were integrated within one common platform. Various tools were designed based on the enabling technologies for synchromodality and combined with an optimization tool to find multi-modal routes and schedules to move freight in strategic and operational settings. The platform was successfully tested on case studies provided by shipping companies.

Platforms such as SYNCHRO-NET require other optimization tools, so we decided to focus on optimization, one of the enabling technologies for synchromodality. We studied the tactical Location-Transshipment Problem, i.e., contracting terminals to transship containers, since terminals have been identified as significant contributors to creating bottlenecks in logistics networks. We designed three models accounting for different characteristics of synchromodality that were not considered before in literature.

The first model considers uncertain handling utilities and available capacities of terminals, proposing a two-stage stochastic formulation. We used this model to study the impact of those uncertainties through several standard Stochastic programming indicators (VSS, EVPI, LUSS, and LUDS). Moreover, we developed a variant of the Progressive Hedging Algorithm to solve the two-stage stochastic model that performed better than commercial solvers and the original method. The second model focuses on flow synchronization, considering cross-docking and just-in-time procedures. We solved the model with a commercial solver to perform economic analysis and derive managerial insights on terminals utilization and flow synchronization. The last model expands the second by introducing other features, such as multi-modal services and multi-commodity flows. Moreover, we introduced a time-space multi-network structure to represent the logistics network of a logistics service provider implementing synchromodality. The model was used for an economic analysis to address how different stakeholders' behaviors affect costs and the utilization of terminals and services.