Computational logistics at work
Coordination and control in transport logistics

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Editorial

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1. Preface

This special issue of Transport Research Part E: Logistics and Transportation Review features a selection of advanced versions of ideas discussed at the International Conference on Computational Logistics 2015, Delft, The Netherlands. In total, 64 papers where presented at the conference, of which 15 where in extended article form submitted for review, ultimately leading to 7 articles published as part of this special issue. The articles focus on **models and approaches for real-time coordination and control of operations in transport logistics**. In other terms, approaches that are able to control in real time the coordination of multiple distributed components involved in the transport processes, such as transport flows over multiple modes including also sustainable modes such as rail and water, intermodality and/or synchromodality. Those approaches should moreover be able to deal with real-time dynamics, e.g., by means of closed-loop control: action plans are not merely determined, but also updated in real-time depending on actual circumstances and knowledge about disturbances.

The significance of this special issue lies in the innovative combination and integration of topics that have not been addressed in a comprehensive way before, at this level of scientific relevance. A general trend, especially in computational logistics, is to strengthen the theoretical and modeling basis that make possible closed-loop real-time control of operations, and anticipate the needs of real time control in design and planning stages. The distributed nature of logistical transport processes (in space, stakeholders, vehicles used, and time dynamics) needs to be taken into account explicitly; inclusion of coordination in optimization and control schemes specifically tailored for transport processes is therefore crucial.

The papers presented in this special issue develop, verify, and apply quantitative approaches for controlling and executing complex transport logistics tasks, e.g., for finding the most efficient schedule for the transport of passengers or goods. The selection of paper here reported clearly presents the challenges of logistics systems, as made up of multiple time scales (from planning to tactical, to operations and real time closed loop control), touching upon multiple modes (maritime, road, railway), and especially rich of coordination and interconnection within different (time or scopes) scales of the same systems, different vehicles of the same modes within one or more interconnected systems, different modes touching upon a interconnection place. Computational models based on quantitative description of the problem at hand, with optimization based, heuristics as well as control-theoretical approaches all show their value in achieving the coordination sought. These models and algorithms are integrated with key innovations from computational science, operations research, control theory and quantitative analysis for getting satisfactory results in appropriate time, even for large-scale problem instances which naturally ask for distributed or coordinated approaches. The underlying ultimate challenge for all those models is the inclusion of unknown dynamics, either because they are not know yet (online systems) or because the systems is prone to deviations from the plan, which requires continuous re-scheduling and control. Sometimes deviations can be included in the planning processes, most of the times those have to be dealt at a later stage when their impact to the system is known (reactive control) or is expected (pro-active control). The results are always revaluated from a business perspective in terms of relevant and clear objectives, where the impact of coordinated control for logistics is showcased.

Everything starts with a design of services that already incorporate coordination constraints. "**Time Constrained Liner Shipping Network Design**", C.V. Karsten, B.D. Brouer, G. Desaulniers, D. Pisinger introduces the liner shipping network design problem. This is the problem of deciding a network for liner shipping, such that coordination between vessels, number of transhipments to be handled and transit time restrictions on the cargo flow are considered. The solution method is an improvement heuristic, where an integer program is solved iteratively to perform moves in a large neighborhood

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search. A key capability is the possibility to apply the proposed improvement heuristic as a real-time decision support tool for a liner shipping company, to find improvements to the network when evaluating changes in operating conditions or testing different scenarios.

Once the logistics networks have been designed, many planning decisions are still affecting the outcomes of the network. Decisions taken at tactical stages involve routes and schedules to be served by vehicles, which in the case of "**Operational Planning of Routes and Schedules for a Fleet of Fuel Supply Vessels**", M. Christiansen, K. Fagerholt, P. Rachaniotis, M. Stålhane concerns fuel supply vessels. Those latter move around ports to service customer ships anchored outside large ports. As many distribution and logistics problem, a rich multi-trip vehicle routing problem formulation can be used, including constraints related to stowage and time-dependent sailing times. Two optimization models based on arc-flow and path-flow are developed, and the comparison determined a superiority of the path-flow model for this test case, in real planning situations. The applicability of such an approach in real-life setting is also important, both as decision support system even in an effective real-time setting when new orders arrive and deviations from the plan occur.

A similar problem, for a different test case is the inter modal long haul planning, which in this case of "**Anticipatory Freight Selection in Intermodal Long-haul Round-trips**", A. Pérez Rivera, M. Mes. This problem is faced by Logistic Service Providers (LSPs) transporting freights periodically, using long-haul round-trips. Each round trip has to service multiple different locations within one region, by picking up and delivering parcels. Also freights have time-windows and become known gradually over time. In this approach, a probabilistic knowledge about future freights allows the LSP to minimize costs over a multi-period horizon. To this end, an Approximate Dynamic Programming method is embedded in a look-ahead planning, showing strong improvements compared to an offline, single–period optimization. Also here, managerial and business insight describe the value of the approach when put into practice.

Tactical planning becomes operational control, when a short enough time ahead is considered. For multimodal systems, coordination occurs between carriers and port related operations. The goal considered by "**Reducing Port-Related Empty Truck Emissions: A Mathematical Approach for Truck Appointments with Collaboration**", F. Schulte, E. Lalla-Ruiz, R.G. González, S. Voss, directly targets the growing concerns for sustainability. Empty truck trips, caused by a lack of coordination among truckers, are responsible not only for logistics costs, but also for a large share of truck emissions, especially in the urban areas which are often very close to mainports. Achieving collaboration among truckers is seen as the major opportunity to address this relevant sustainability issue. Truck appointment systems schedule truck activities and enable collaboration for transportation between terminals and client locations. The requirements for a truck appointment system define formally the problem, introduce the concept of soft time windows, determine an optimization model based on the multiple traveling salesman problem with time windows, leveraging collaborative planning to reduce costs and emissions. Business results show that the approach appropriately coordinates truck schedules and effectively reduces truck emissions and costs.

A high amount of coordination is also required in case of highly constrained systems such as railway networks. "**Integrating Train Scheduling and Delay Management in Real-time Railway Traffic Control**", F. Corman, A. D'Ariano, A.D. Marra, D. Pacciarelli, M. Samà, defines optimization models for railway traffic rescheduling tackle the problem of determining, in real-time, control actions to reducing the effect of disturbances in railway systems. The paper merges two lines of models achieving both microscopic feasibility, for business acceptance, as well as macroscopic optimization for precise understanding of the impact of real time decisions towards commodities, in this case, passengers. Several fast heuristic methods are proposed, based on alternative decompositions of the model. Computational experiments, based on multiple realistic railway test cases show that good quality solutions and lower bounds can be found within a limited computation time.

Similar coordination problems occur when more logistics networks have to be synchronized, which is typical for synchromodal systems. "**Distributed model predictive control for cooperative synchromodal freight transport**", L. Li, R.R. Negenborn, B. De Schutter investigates cooperative synchromodal freight transport planning among multiple intermodal freight transport operators in different and interconnected service networks. A cooperative model predictive container flow control problem, is solved with three approaches, building on parallel, serial schemes based on Augmented Lagrangian Relaxation or an approach based on the Alternate Method of Multipliers approach. The models achieve an interesting trade-off in terms of the least iterations and information exchanges required, or the least amount of actual computation time.

Planning, tactical an operational plans have to be finally integrated into vehicle control. The paper "**Closed-loop scheduling and control of waterborne AGVs for energy-efficient Inter Terminal Transport**", H. Zheng, R.R. Negenborn, G. Lodewijks, deals with this issue, with the peculiar transport model of waterborne Autonomous Guided Vessels (waterborne AGVs), where a high degree of autonomy is envisaged. The model is recast as a pick-up and delivery problem considering safety time intervals between berthing time slots of different waterborne AGVs. Waterborne AGVs are controlled in a cooperative distributed way to carry out the assigned schedules. Real-time scheduling and control loop is closed by a partial scheduling model and an interaction model with feedback reflecting neglected lower level factors. Real-time feedback is achieved in both scheduling and control levels, which allows the waterborne AGVs to carry out the scheduled tasks in a cooperative distributed way, for an effective automated transport link.

Summarizing, the field of logistics is particularly active in the uptake of ICT and computational, quantitative techniques. The scientific advances provided by the papers in this issue relate to new mathematical models and approaches that yield improved performances in the real-time control of the logistics chain. In fact, the possibility to exploit a vast amount of information available asks for development of advanced control models able to master the complexity and distributed setup of transport logistics. Those approaches are what makes it possible to use, in real-time, automated computational procedures to deliver control actions and decisions—i.e., to put computational logistics at work in transport and logistics.

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