Optimum Routing of Freight in Urban Environments under Normal Operations and Disruptions using a Co-simulation Optimization Control Approach

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Project Objective

The purpose of this project is to use complex real time simulation models to estimate the states of the transportation network and integrate that knowledge with optimization and load balancing techniques in an iterative feedback configuration that would lead to much more efficient routing decisions during normal operations and disruption.

Problem Statement

The complexity and dynamics of multimodal freight transportation together with the unpredictability of incidents, disruptions and demand changes make the optimum routing of freight a challenging task. Optimum routing decisions in a multimodal transportation rely on the estimation of the dynamical states of the multimodal traffic network. Such estimations rely on mathematical models that are often oversimplified and highly inaccurate leading to routing decisions that deviate considerably from optimality. In addition, they do not take into account the impact of the routed freight on the states of the network, the values of which were used to generate these routes in the first place. In this project we formulated the problem of multimodal freight routing that aims to minimize the total delivery cost under the constraints of traffic network dynamics, road/rail capacity, and supply-demand requirements. The explicit forms of the dynamical functions in the formulated problem are difficult to mathematically express directly due to the nonlinearities and complex variable interactions. Therefore, we develop a co-simulation optimization control (COSMO) approach to solve the problem by taking advantage of real time simulations.

Research Methodology

The traffic network simulation models are used to replace the mathematical functions in order to generate more accurate network states and costs. The new minimum cost route is found based on updated network states and the use of the column generation methodology to solve the problem iteratively.

The COSMO approach works as follows: Real time data that reflect changes in demand or incidents or traffic changes are fed to the simulation model which updates itself continuously. The simulation model generates the flows in all links of the network under consideration and uses these estimated flows to calculate the costs along every link. This information is used by the optimization to calculate the minimum cost route for an initial choice of freight load distribution. Since the freight load will affect the link cost in a nonlinear manner that is not known the initial choice of a minimum cost route may no longer be minimum after the deployment of freight load. If this is the case the load balancing module makes an adjustment which leads to new link costs and therefore to possible new routes of minimum cost as computed by the optimization part. This leads to an iterative procedure which continues till certain stopping criteria are satisfied. The final solution then becomes ready to be applied to the actual freight network. Unpredictable changes in the freight network characteristics are captured by the model and taken into account therefore the proposed approach can deal with disruptions and all kind of emergencies and incidents in the network.

Results

The simulation models used in the COSMO approach of this report consist of a macroscopic road network model and a rail simulation model. We use the macroscopic traffic simulator VISUM to model the traffic flow in an area that includes the LA/LB ports and adjacent road network shown in Fig. 1,2. We evaluated the routing between six main destinations (D1 – D6) and three terminals (A, B, C) in the region with different demands. The COSMO approach leads to substantial improvement reduction especially in the case of unpredicted events such as congestion and accidents an initial solution did not anticipate as shown in Figure 3.

Figure 1. Region of study

Figure 2. Road network simulation

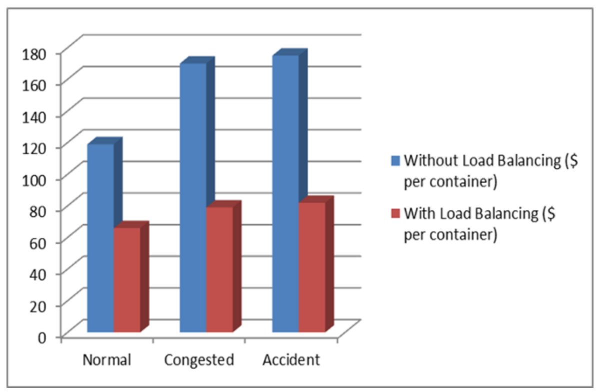

Figure 3. Evaluation Results