Towards an integrated multi-agent urban transport model of passenger and freight

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Submission date: 01.04.2015

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1 Objectives and motivation

There is no doubt that urban freight significantly contributes to the wealth of cities and urban economies. However, even urban freight constitutes a relatively small proportion of urban transport, its negative impacts (e.g. road congestion, air quality issues, noise etc.) are disproportionally high.

Therefore transport policy defines ever more challenging goals such as CO2-free urban logistics [EU, 2011]. A number of reasons has led transport policy to change its strategy from “predict and provide” to demand management, i.e. measures that are tailored to specific actors to alter their behaviour by changing their transport context. However, these measures need to be evaluated in advance to identify their effects on the transport system and the environment and to identify winners and losers of such measures. Thus, models are required that can map high spatial resolutions, the interactions of passenger and freight in constrained physical networks, the ever-increasing heterogeneity in urban freight transport (logistics) and behavioural adaptations to policy measures. This constitutes a major challenge for transportation research.

A couple of models map urban commercial vehicle flows as a whole. Most of them focus on constructing tours and activity chains (e.g. Hunt and Steflan [2007] and Johan W. Joubert and Axhausen [2010]). They are well defined to support classical transport planning. Once it comes to the assessment of measures tailored to individuals, their sensitivity is still limited. One reason is that these models focus on individual vehicle movements rather than logistics behaviour yielding to these movements. City logistics models address logistics behaviour and seek to optimise ”the logistics and transport activities by private companies in urban areas while considering the traffic environment, traffic congestion and energy consumption within the framework of a free market economy” [Taniguchi et al., 2001] (see Taniguchi et al. [2014] for recent trends). The traffic environment and traffic congestion in these models are mostly represented by exogenous parameters. A number of policy measures, however, impact the whole transport system, e.g. a prohibition for heavy vehicles in the city centre, and thus influence these exogenous parameters itself. One way to deal with these interdependencies is to consider some of them within the model. This, however, requires models with high spatial and temporal resolution that can map both passenger and freight transport. Such models are still scarce.

We developed a multi-agent freight transport simulation and integrated it into an existing passenger simulation to model both passenger and freight actors (Schröder et al. [2012] and Schröder and Liedtke [2014]). The objective of this paper is twofold. First, we study the sensitivity of this model according differentiated policy measures. Second, we analyse different strategy configurations and their impact on the model outcome and performance.
2 General description

This work is part of integrating freight carriers as autonomous agents in a multi-agent transport simulation called MATSim. MATSim-Freight consists of a traffic simulation and microscopic demand models for passengers and freight. The traffic simulation is based on a queue model that simulates the movement of individual travellers and commercial truck drivers in the physical system. The demand models captures the reasons behind actual movements, i.e. the choice dimensions to "efficiently" conduct activities. Since the modelled actors have different preferences and goals as well as different capabilities, each actor is in the model represented by an unique agent. The decisions of each agent are encoded in an agent’s plan. The traffic simulation then executes these plans concurrently. Congestion effects and resulting delayed arrival times are fed back into the demand models where agents can evaluate their plans. They evaluate their plan with individual utility/cost functions quantifying for example travel times and distances, activity durations as well as delayed arrival times (this is step is called scoring). In the course of a model run, each agent can improve its plan by modifying an existing one. Based on the agent’s experiences in previous iterations, it can choose for example another route, another transport mode, it can shift activities’ departure times or when it comes to freight transport it can choose whole new activity sequences. These decisions yield new plans, thus, this step is referred to as re-planning. A traffic equilibrium is achieved by the iterations of three steps: (re-)planning, physical traffic simulation, scoring.

In this work, we study the sensitivities of the model outcome according to policy scenarios and to changes in the strategic configuration of freight agents. To be more precise, each freight agent employs a set of behavioural modules to improve its plan in the course of the model run given a transport system context. For example, they can employ a vehicle router every 10th iterations, or they can apply a least costs path algorithm to find new network routes every second iteration. We test different strategic configurations and evaluate their impacts on the model outcome, speed of convergence and the computational performance, and additionally we vary the transport system context by implementing policy measures that differentiate between area, daytime and vehicle type.

We study these sensitivities in a sandbox scenario which consists of a chessboard network, a passenger population of 324 passenger agents living and working in this scenario, and a freight population consisting of 36 freight carriers with different capabilities (e.g. no. of depots, vehicle types) each having 20 randomly distributed customers. Whereas passengers maximise their utility (i.e. activity performing utility, travel and waiting disutility etc.), freight carriers minimise their costs function, i.e. fixed and variable transport costs.
3 Results and conclusions

The analysis show that the model is sensitive to changes in the transport systems imposed by transport policies, i.e. freight agents alter their transport behaviour accordingly. The study shows also that the impact of a policy scenario on carriers’ costs can be reinforced by the presence of passengers, i.e. a prohibition of heavy vehicles to access the city centre in the early morning does not only reduce their available time window, but also shift freight transport in the morning rush hour of passengers which in turn increases travel time. Additionally, the analysis shows that reducing the frequency (every n-th iteration) for each freight agent to re-plan whole new vehicle routes does not worsen the model outcome and individual costs significantly, however, at the same time, it has rather positive effects on the overall computational performance. Even our approach has a number of limitations which we discuss in the paper as well, we think it is a promising tool to support urban transport policy.

References


