Extensions for logistic and public transport in SUMO

Andreas Kendziorra and Melanie Weber;
German Aerospace Center , Rutherfordstraße 2, 12489 Berlin, Germany

{Andreas.Kendziorra, Melanie.Weber}@DLR.de

Abstract

Disasters or major events affect the efficiency of passenger and freight transportation. The project VABENE++ considers the question what happens when the road network is disturbed due such an event. Within this project, the German Aerospace Center developed a decision support tool that provides consolidated information and operation recommendations regarding individual motor car traffic based on traffic simulation performed by SUMO. Recently, it was aimed to realise simulation scenarios in which incidents impairing the road network occur, and that focus on multimodal transportation systems. To enable this, the implementation of public transport and logistics in SUMO were extended. The present paper presents these extensions in detail and outlines its usefulness in examples.

Keywords: SUMO, Logistic, Transport, Public Transport, Railway

1   Introduction

Transport and traffic is one of the identified critical infrastructures in Germany [1]. A disturbance of the traffic network can have serious influences on passenger transportation, freight transportation and the supply of necessary goods and services. These disturbances can be manifold. They may be plannable, like major events, or unpredictable, like accidents, natural disasters (e.g. floods, earthquakes) or from human malevolence, such as acts of sabotage, terrorism or war. To support decision makers, like authorities and emergency forces, in such critical situation, the decision support system *EmerT Portal* was developed within the project VABENE [2]. Until recently, the system considered only motorised individual traffic. Due to the fact that not only this means of transport is affected by an extraordinary occurrence, this system was expanded by more means of transport. One part of this system is the traffic simulation software SUMO [3]. Public transport (bus, tram and train) and pedestrians were already a part of SUMO prior to the expansion, however in a basic fashion. The implementation of logistic transport is novel in SUMO. To set up a simulation scenario with a multimodal transportation system, SUMO had to be extended. The implemented extensions will be presented in this paper in the following order. In Section 2, the extensions regarding public transport will be presented. The implementation of the logistic concept will be explained in Section 3. In Section 4, some examples using the presented extensions will be shown. Finally, the conclusions and an outlook will be given in Section 5.

2 Public transport Extension

2.1 Existing concept

So far, simulating public transport within SUMO is possible, however, with limited capability (see [1, 2]). The most necessary concepts already implemented for this kind of simulations are *persons*, *vehicles* and *stops*.

Persons are objects that can *walk*, use a vehicle (*ride*) and *stop*. Each person must have a plan which is a sequence of these stages. For walking, a person is following a given sequence of edges. Thereby, the walking behavior depends on the chosen *pedestrian model*. The most advanced pedestrian model implemented in SUMO so far is the model "striping"; a 2D-model that enables walking side by side on sidewalks and includes a collision avoidance algorithm for persons that walk towards each other [3]. For a ride, a person has a list of *lines* (vehicles can be assigned to lines which can be used particularly for buses, trams and trains) and *ids* of vehicles to use. At the beginning of a riding stage, a person is positioned at an edge. Whenever a vehicle that corresponds to a line or an id of the given list stops at this edge, the person will board the vehicle. When the transporting vehicle stops at the destination edge of the ride, the person will leave the vehicle and will proceed with the next step of its plan. Stopping can be used to simulate activities such as working, shopping or doing sports. For that, a duration or a fixed end time, as well as a lane, have to be defined. For example:

```
<routes>
   <person id="1" depart="0">
      <walk from="edge1" to="edge2" departPos="10.0" arrivalPos="20.0"/>
      <ride from="edge2" to="edge3" lines="a"/>
      <walk from="edge3" to="edge4" arrivalPos="30"/>
      <stop lane="edge4_0" duration="20" startPos="40"/>
      <ride from="edge4" to="edge5" lines="b"/>
   </person>
</routes>
```

Vehicles have the capability to transport persons. For that, there exist no restrictions on how many persons a vehicle can transport. Moreover, there is no duration for a person to board a vehicle and any number of persons can board a vehicle in one time step. Also, there are no requirements regarding the distance between the vehicle and the boarding person. The only requirement is that both have to be positioned at the same edge.

There exists a very particular procedure of departure for vehicles, called *depart triggered*. A depart triggered vehicle has no depart time but will depart when a person boards the vehicle. This can be used to simulate parking vehicles.

As stated above, vehicles can be assigned to lines. This is in particular useful for buses, trams and trains. For example, buses that have the same route can be assigned to one line. Therefore, one can tell a person to use a bus of a certain line without choosing a particular bus. Moreover, it is possible to define *flows* of vehicles. That means, vehicles that have the same attributes, except their id and their depart time, are inserted periodically with a fixed frequency into the simulation. In particular, bus and tram lines can be defined via flows.

As already mentioned, persons can have stops as stages of their plan. However, stops can be used for vehicles and routes in general as well. In these cases, one can define further attributes. Amongst others, the start and end position at the lane can be defined. That means, a vehicle will stop within this interval. A more advanced concept of stops is a *bus stop*. The difference is a more elaborated approaching behavior of the vehicles (mostly buses) towards the bus stop.

2.2 Person capacity and person number Extension

To resolve the unrealistic fact that a vehicle can transport an unlimited number of persons, the parameters *person capacity* and *person number* were introduced. Person capacity is a vehicle type parameter that specifies how many persons (excluding an autonomous driver) a vehicle can transport. For every vehicle class, there exists a default value for the person capacity (see [7] for a list of the default values), but it can also be set in the definition of a vehicle type (e.g. <type vClass="passenger" id="pkw1" personCapacity="4"/>). The person number states how many persons (excluding an autonomous driver) a vehicle is actually transporting. If the person number of a vehicle is equal to its person capacity, no further person can board this vehicle.

2.3 Boarding behavior Extension

Some modifications regarding the boarding behavior of persons were implemented. As already mentioned, a person can board a vehicle only if the person number of the vehicle is smaller than its person capacity. Moreover, some restriction about the distance of the vehicle and the boarding person were incorporated. If a vehicle is stopping at a stop and a person wants to board the vehicle, the person's position has to lie within the stop. That means, the person's position on the lane has to be larger than the start position and smaller than the end position of the stop. For depart triggered vehicles, a person positioned outside of the stop of the vehicle can still board the vehicle if the person's position has a distance of at most 10 meters to the vehicle.

Another enhancement is the implementation of the vehicle type parameter *boarding duration*. This parameter states how long it takes one person to board the vehicle. Only one person can board the vehicle at a time. Therefore, if n persons want to board one vehicle for an $n \in \mathbb{N}$, and $t \in \mathbb{R}$ is the boarding duration of the vehicle, the time required to let all persons board the vehicle equals $n \cdot t$. For example, if 12 persons waiting at a bus stop want to board a bus whose boarding duration equals 0.5 seconds, it takes 6 seconds until the last person boarded the vehicle. If the duration of the boarding of all persons exceeds the stop duration of the vehicle, the stop duration will be extended by the necessary amount of time.

Due to the changes regarding the boarding behavior and the implementation of the parameters person capacity and person number, scenarios using public transport can be simulated more realistically. For example, bottlenecks due to low capacities of vehicles (e.g. buses and trams) or extended travel times due to long boarding durations can be considered or may be identified in simulations.

3 Logistic Extension

A concept for freight and goods was implemented to enable the simulation of goods traffic. This concept consists basically of the new objects called *containers* which represent goods of all kinds. For example, one can represent an ISO container, a tank container, an arbitrary amount of bulk material, an arbitrary amount of animals etc. as a container.

The concept of containers is very similar to the one of persons. Containers are objects that can be transported by a vehicle (*transport*), *stop* and that can be transhipped between two places (*tranship*), e.g. to simulate the transhipping of a container from a rail station to an adjacent harbor (which can be represented as a stop at a waterway). The mode *transport* is equivalent to the mode *ride* for persons, and *stop* is equivalent to *stop* for persons. *Tranship* defines a direct transhipping of containers between two points. Thereby, containers do not move along edges. They move in a straight line with constant velocity, no matter if the line is crossing buildings or anything else (see Figure 1). Therefore, the time required for a tranship-stage depends on the Euclidean distance between the two points and the chosen velocity (default velocity is 5 km/h).
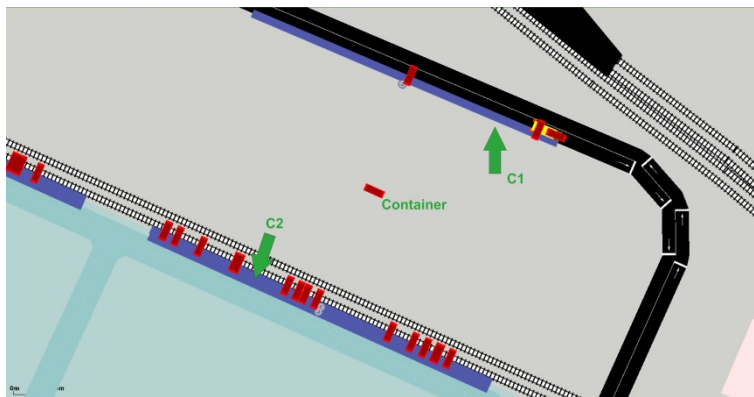

Figure 1. A container gets transhipped from container stop C1 to container stop C2; thereby, the container moves straight from its depart position on C1 to its arrival position on C2

As with the concept of persons, containers must have a plan which is a sequence of these stages. For example:

```
<routes>
    <vType id="DEFAULT_VEHTYPE" sigma="0" containerCapacity="1"/>
    <container id="container0" depart="0">
        <tranship from="edge1" to="edge2" departPos="80" arrivalPos="55"/>
        <transport from="edge2" to="edge3" lines="train0"/>
        <tranship from="edge3" to="edge4" arrivalPos="30"/>
        <stop lane="edge4_0" duration="20" startPos="40"/>
        <transport from="edge4" to="edge5" lines="truck0"/>
    </container>
</routes>
```

A complete description of all available parameters of the three stages of containers can be found at [8].

Similarly to the concept of bus stops, *container stops* were introduced at which containers can be loaded onto or unloaded from a vehicle. Vehicles use the same advanced approaching behavior at container stops as at bus stops. They can be used to simulate transhipment stations, harbors and other places for transhipping and storing containers/goods.

To enable a realistic loading behavior, analogously to the new boarding behavior of persons, the parameters *container capacity*, *container number* und *loading duration*, which correspond to the parameters *person capacity*, *person number* and *boarding duration* for persons, were introduced.

4 Examples

4.1 Public transport

A scenario involving persons and public transport was used to test the enhancements regarding public transport. More precisely, it was examined if unfavourable relations between the amount of people using public transport and the capacity of the public transport system affect the state of the traffic. As expected, one could find situations in which bus stops get crowded due to low frequencies of bus lines such that the busses cannot transport the amount of people intending to ride a bus of this line (see Figure 2). This results clearly in longer travel times for persons.
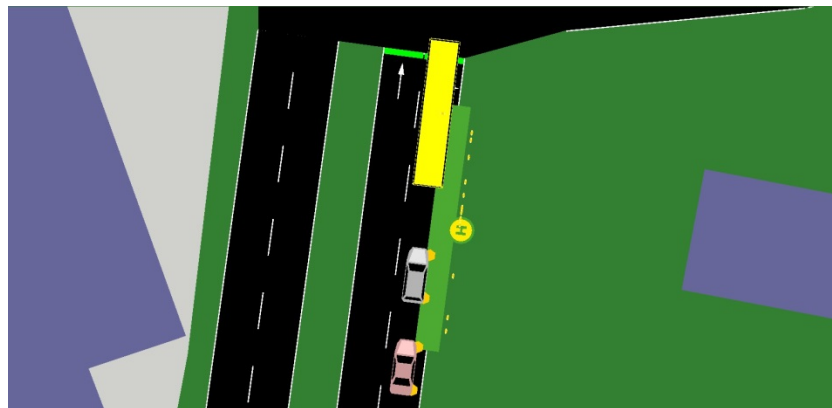

Figure 2. A fully occupied bus leaving people behind at a bus station due to a too low capacity of the bus line with respect to the amount of people; travel time of people left behind extends accordingly

Other expected consequences are congestions due to blocking busses at bus station. This occurs when many people board a bus such that the bus blocks the corresponding lane for a long time. In Figure 3, a situation can be seen at which 80 people board a bus with a boarding duration of 0.5 seconds. Consequently, the bus blocks the right lane for 40 seconds, which results in congestion on the right lane, as all cars intending to turn right are blocked.

Figure 3. 80 people boarding a bus cause the bus to block all right turning vehicles for 40 seconds, resulting in a congestion on the right lane

4.2 Logistics

A scenario was developed to test and demonstrate the functionalities of the logistics extensions. The scenario considers the goods traffic around the harbor of Brunswick, Germany. Goods are transhipped, stored and transported by trains, ships and trucks within the scenario. An overview of the harbor area of the scenario can be seen in Figure 4.

The harbor consists of seven landing stages, and for each landing stage there exists a corresponding goods station for trains, as well as a container stop for trucks next to the road. In this scenario, almost all the goods are transported by a vehicle (truck, ship or train) to the harbor area, where the container gets transhipped to another container stop, gets stored for a while and finally transported by another vehicle (see Figure 5 and Figure 6).

Figure 4. The harbor of Brunswick in the SUMO-simulation; containers are displayed in red, vehicles in yellow and container stops in blue
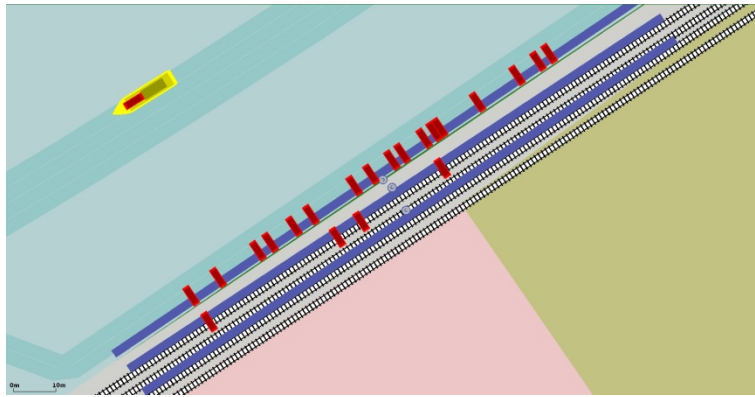
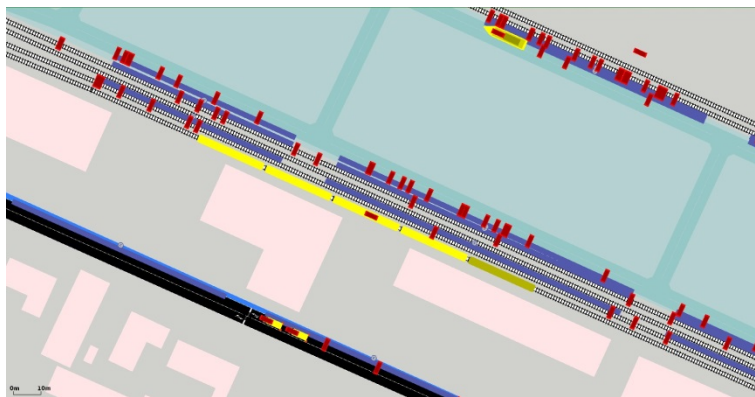Figure 5. Stored containers at a landing stage (container stop) of the harbor

Figure 6. Containers get loaded/unloaded onto/from ships, trains and trucks

5 Conclusion and discussion

It was aimed to expand the existing public transport concept and to implement a first version of a logistic transport concept in SUMO to create the possibility to set up simulation scenarios with a multimodal transportation system. The enhancements allow simulations of public transport with a realistic boarding behavior. Buses block the traffic when many people to board them, and people also wait for the next bus when the current one is fully occupied. In addition, major events and disaster involving persons can be better simulated. For example, in the case of a major accident, replacement buses are often inserted. With the help of the simulation, one can identify bottlenecks due to a too low number of replacement buses. The implementation of public transport reached a quite elaborated state and only less essential extensions are thinkable. For example, an intermodal router for passengers could be implemented.

The implemented concept for freight and goods enables the simulation of goods traffic. The concept is very similar to the extended public transport concept. Due to the implementation, intermodal logistic chains can be realised now. For the future, several extensions are possible. These include a goods router or the enhancement of the goods concept, such that not only container but also pallets or individual items can be transported. One could also enable that certain goods, such as food, bulk or liquids/gases, can be transported only by special vehicles. Furthermore, one could enable restrictions for the route of vehicles transporting hazardous

material or heavy load. Another extension that is needed for more realistic freight transport is the implementation of a rail signal concept. So far, trains behave on rail networks as cars behave on road networks. In reality, the rail network is divided into blocks and trains can enter a succeeding block only if they get signalised that there is no train in the succeeding block.

It can be summarised that the extended SUMO is able to simulate logistic and public transport which was proven in example scenarios. Further expansions are possible, however, mostly with respect to logistic as the implemented concept for public transport is quite advanced.

References

[1] Bundesministerium des Inneren, „Nationale Strategie zum Schutz Kritischer Infrastrukturen (KRITIS-Strategie)," 2015. [Online]. Available: http://www.bmi.bund.de/cae/servlet/contentblob/544770/publicationFile/27031/kritis.pdf. [Zugriff am 27 1 2015].

[2] German Aerospace Center, „VABENE++ Traffic Management for Large Scale Events and Disasters," [Online]. Available: http://www.dlr.de/vabene/en/desktopdefault.aspx. [Zugriff am 4 2 2015].

[3] M. Behrisch, L. Bieker, J. Erdmann und D. Krajzewicz, „SUMO - Simulation of Urban MObility: An Overview, Proceedings of SIMUL 2011," in *The Third International Conference on Advances in System Simulation*, Barcelona, 2011.

[4] M. Behrisch, J. Erdmann und D. Krajzewicz, „Adding intermodality to the microscopic simulation package SUMO," in *MESM 2010*, Alexandria, 2010.

[5] J. Erdmann, „Multimodalität und Nachfragegenerierung mit SUMO," in *Workshop Intermodalität*, Berlin, 2013.

[6] J. Erdmann und D. Krajzewicz, „Modelling Pedestrian Dynamics in SUMO," *preprint,* 2015.

[7] German Aerospace Center, „SUMO Wiki," [Online]. Available: http://sumo.dlr.de/wiki/Vehicle_Type_Parameter_Defaults. [Zugriff am 4 2 2015].

[8] G. A. Center, „SUMO Wiki - Container," [Online]. Available: http://sumo.dlr.de/wiki/Specification/Containers. [Zugriff am 25 03 2015].