Electric Vehicles

Rashid A. Waraich and Joschka Bischoff

Entry point to documentation:

`http://matsim.org/extensions` → transEnergySim

Invoking the module:

No predefined invocation. Starting point(s) under `http://matsim.org/javadoc` → transEnergySim → `RunTransEnergySimExample` class.

Selected publications:

Waraich et al. (2013d); Galus et al. (2009, 2012b); Waraich (2013); Galus et al. (2012a); Waraich (2012a,b); Waraich et al. (2014a); Waraich and Axhausen (2013)

14.1 Introduction

Research related to EV modeling in MATSim started in 2008/2009, with an electricity grids project (Waraich et al., 2013d); it's goal was to uncover potential bottlenecks and/or constraint violations in Zürich city's lower voltage grid due to future EV charging. A framework emerged from the research for EV modeling, called TESF (Transportation Energy Simulation Framework) (Waraich et al., 2014a). This resulted in various framework extensions and enabled simulation of various scenarios (Waraich et al., 2014a; Waraich, 2013; Abedin and Waraich, 2014; Schieffer, 2011; Galus and Andersson, 2011; Galus et al., 2012a; Bischoff, 2013; Bischoff and Maciejewski, 2014). This chapter provides advice on these research directions and serves as a starting point for modeling EVs in MATSim.

14.2 Models

The main reason for modeling EVs in TESF was simple: it was essential to keep track of the battery charging state in the EVs. This meant that, as the EV was driving, depletion of the

batteries was simulated. It was also important to consider the charging process of EVs at charging infrastructures.

While the basic EV modeling mechanisms were simple, there were many details to ponder when modeling scenarios. The TESF framework provided both interfaces and implementations to cope with more complex cases, e.g., defining a vehicle that can charge without contact while driving, for example, by using dynamic inductive charging. Furthermore, charging mechanisms themselves could also be quite complex. The following sections provided some details on this, as well as different models involved.

14.2.1   Energy Consumption Model

When a vehicle was defined in TESF, it could be assigned an energy consumption model, defining how much energy the vehicle used while driving. For conventional vehicles, just energy consumption could be logged using such a model; however, for electric vehicles, the energy consumption model was used to update the on-board battery system state of charge. PHEVs (Plugin Hybrid Electric Vehicles) can use both electricity and gasoline for driving and therefore had two different energy consumption models assigned to them for modeling these two modes. When this was written, a series hybrid model were implemented in TESF (Chan, 2007), which used electricity as long as the battery charge state was above a certain threshold value, then switched to gasoline. This type of vehicle could also be charged using a plug, like a battery electric vehicle. For PHEVs, car manufacturers often defined rules governing when a vehicle should switch between battery and gasoline use. The TESF framework provided interfaces and examples of how more advanced control strategies for PHEVs could be implemented.

14.2.2   Charging Infrastructure

In addition to plug-based charging, inductive charging infrastructure was also modeled in TESF, with two types: dynamic and stationary. The dynamic inductive charging infrastructure was often embedded in roads; vehicles able to use such infrastructure could charge while they drove. Stationary inductive charging was, more or less, modeled like plug charging; however, charging interfaces between vehicle and the charging infrastructure had to match for the charging process to function.

Another fast route to a full battery was to replace/swap the used battery for a new one at a specialized infrastructure, sometimes referred to as a swapping station (Li et al., 2011). A basic modeling of this approach was provided in TESF, which could be extended and detailed further according to specific scenario needs.

14.2.3   Charging Schemes

When an EV connected to any infrastructure for charging, a scheme was needed to define how the vehicle charging would operate; should the vehicle start charging immediately, or would charging depend on an agent's pricing preferences, which could vary with time and location? Negotiations between the vehicle computer and grid operator were also possible, which perhaps allowed for some electricity grid temporal flexibility, while fully charging a vehicle's battery before departure (sometimes referred to as "smart charging"). Various charging schemes were part of the TESF and were be used to model other more complex charging schemes; TESF-simulated examples of various charging schemes can be found in Waraich et al. (2013d).

14.2.4   Vehicle-to-Grid

When studying electric vehicles, charging is not the only topic of interest; V2G (Vehicle-to-Grid) applications where electric vehicle batteries supply power and energy back to the grid (Kempton

and Tomic, 2005) were analyzed. While the integration of V2G models for MATSim was limited at any given time, an application related to V2G and intermittent energy generation at wind parks using MATSim can be found in Galus and Andersson (2011) and a preliminary attempt to integrate V2G in TESF was described in Waraich et al. (2014a); Schieffer (2011).

14.2.5 Vehicle Choice

When conducting electric vehicle studies, each vehicle owner usually has to be assigned a specific type: e.g., electric vehicle, conventional vehicle, plug-in hybrid, etc. Sometimes, these assignments were random, while ensuring vehicle type share constraints for the scenario (e.g., Waraich et al., 2014a). Often, however, possible financial or infrastructural incentive implications, e.g., different toll prices, parking fees or fuel prices for different vehicle types, had to be evaluated. A replanning module for vehicle choice, also covering EVs, was recently implemented; first results should published soon and can also be integrated in TESF.

  This section provided an overview of the various TESF framework parts and the following section an application of a TESF contribution, that modeled electric taxis.

14.3   Application: Electric Taxis

Combination and extension of both the TESF and VRP (Vehicle Routing Problem) contribution (see Chapter 23) allows simulation of BEVs (Battery Electric Vehicles) taxi fleets. For electric vehicles, vehicle charging process was adapted; for taxis, the concept of taxi ranks and a modified optimizer sending idling taxis to the rank and only dispatching vehicles with sufficient battery charge were introduced.

14.3.1   Taxi Ranks

After dropping off passengers, taxis proceeded to the nearest rank location, unless there was an immediate follow-up request. Queuing took place at the rank location; the taxi that arrived first would leave the rank first. Other types of queuing were also tested, e.g., a dispatch by battery SOC (State of Charge). Ranks were not mandatory; however, driving there between trips would be typical German taxi driver behavior.

14.3.2   Charging Process

Chargers could be located at taxi ranks or any other link. Following any given BEV `AgentArrivalEvent` at a charger location link, charging would begin if

- there was a free charging spot,
- the vehicle's SOC was under a certain threshold,
- at least two minutes of time passed required for parking the car and plugging it in.

  Electric taxi simulation has been used in Mielec, Poland (Bischoff, 2013; Bischoff and Maciejewski, 2014). When this was written, an application for Berlin was in progress.

14.4   Usage

The TESF contribution contained many features described above and interfaces were provided for framework extension. Examples were also given for the setup of different scenarios: e.g., energy consumption model, vehicle types, charging schemes, etc.