Chapter 75
Adding Electric Vehicle Modeling Capability to an Agent-Based Transport Simulation

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ABSTRACT

Battery-electric and plug-in hybrid-electric vehicles are envisioned by many as a way to reduce CO_2 traffic emissions, support the integration of renewable electricity generation, and increase energy security. Electric vehicle modeling is an active field of research, especially with regards to assessing the impact of electric vehicles on the electricity network. However, as highlighted in this chapter, there is a lack of capability for detailed electricity demand and supply modeling. One reason for this, as pointed out in this chapter, is that such modeling requires an interdisciplinary approach and a possibility to reuse and integrate existing models. In order to solve this problem, a framework for electric vehicle modeling is presented, which provides strong capabilities for detailed electricity demand modeling. It is built on an agent-based travel demand and traffic simulation. A case study for the city of Zurich is presented, which highlights the capabilities of the framework to uncover possible bottlenecks in the electricity network and detailed fleet simulation for CO_2 emission calculations, and thus its power to support policy makers in taking decisions.

INTRODUCTION

Battery and Plug-in Hybrid Electric Vehicles (BEV resp. PHEV) are seen by many as a key component to a future transport sector with lower greenhouse gas emissions. These vehicles do not only have a more efficient driving cycle than conventional vehicles, but also allow a diversification of energy sources for driving (MacKay, 2008). BEV and PHEV are abbreviated to electric vehicles (EV), with the exception of cases where the distinction is required.

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Several governments have announced national goals regarding the number of EVs they want to have on their roads. Examples include the USA with one million EV until 2015 (White House, 2009) and Germany with the same number of vehicles until 2020 (Bundesregierung, 2009). At the time of this writing almost all major car manufacturers have either introduced a plug-in electric vehicle or are planning to do so, (see e.g. de Santiago et al., 2012).

While these numbers highlight the fact that a shift towards an era probably dominated by EVs has started, there are also many uncertainties connected with such an introduction, leading to many open questions:

Although these vehicles will require additional electricity for charging, it is not clear if the supplementary electricity can be generated in a sustainable way. Even if the required energy is coming from alternative sources, such as solar or wind power, further questions arise, such as can electricity generation match the time of electricity demand? Could the Vehicle-to-Grid (V2G) concept help in this regard, where batteries of the vehicles could act as a power reserve (Brooks, 2002; Kempton & Tomić, 2005)? Could a viable V2G model be built around ancillary services, where car batteries are used for voltage and frequency regulation (Hirst & Kirby, 1999; Kirby, 2004) and which is rewarded with a higher return than if vehicle batteries act only as power reserve (Letendre et al., 2006)? With this said however, there is a possibility that such utilization of batteries could also reduce their life span in such a way that V2G is no longer attractive (Kramer et al., 2008).

Additional questions arise around the charging infrastructure: While PHEV in the sense of all hybrid electric vehicles can both charge their batteries from the electricity network as well have a backup gasoline tank, BEV depend on a functioning charging infrastructure system. So what is the right way to provide such an infrastructure? Which are the places where such infrastructure should be built first? Will normal charging plugs or higher powered plugs allowing for faster charging prevail? Or will future cars have swappable batteries, allowing for their energy to be replenished even faster than filling up a gasoline tank (Li et al., 2011)? In addition, do new technologies for charging, such as inductive charging along roads, which charge the vehicle during the drive (Wu et al., 2011) or solar panels mounted on top of the cars have a place as part of the overall charging infrastructure (Li et al., 2009)? As vehicles with bigger battery capacity require less public charging infrastructure, could it be the case that EV with high capacity batteries might make public charging infrastructure obsolete? Or will such a mass production of large batteries never become reality? What is the best investment for public funding, e.g. subsidizing public charging infrastructure or car batteries?

There are also many open questions which arise in relation to the electricity network: While it is often suggested (Parks et al., 2007), that EVs could charge during off-peak demand during the night, there are also studies which suggest that well-meant pricing incentives could backfire and cause more damage than good, even potentially generating new peaks (Waraich et al., 2009). They demonstrate that to solve such problems, communication technologies could be used in order to match supply and demand, in general referred to as smart charging/grid (Amin & Wollenberg, 2005). In conjunction with V2G and distributed energy generation, such technology becomes even more relevant. In this case, a building with solar panels in times of a local/temporal surplus, can feed energy into the electricity network. Furthermore, the usage of home appliances and charging of EVs could be delayed when there is an electricity shortage in the electricity network. How can such complex scenarios be modeled? While the energy increase due to electric vehicles is predicted to be small compared to the overall electricity load (Duvall et al., 2007), charging may still not be possible due to problems in the