# Simulation based planning processes for the integration of inductively charged vehicles into public transportation services

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**Introduction**
Economy and reliability are requirements that innovative vehicle concepts for public transport operations need to fulfil. In the context of inductive charging, the interdependency between the dimensioning of power electronics and drive aggregates of the vehicles and the charging infrastructure need to be taken into consideration.

**Problem – Complexity in the planning of the operation of electrically powered vehicles**
Due to the long duration of usage, correct positioning and dimensioning of infrastructure is essential. Furthermore, life-cycle costs of stationary infrastructure and compatible vehicles need to be reflected. The battery significantly determines the investment and the vehicle weight. This has to be weighed up against the required high level of operational availability. The planning process of the introduction of electrically charged vehicles aims for the maximization of operational availability. An increased up-time can be achieved through the energetic optimization of drive-cycles and traffic flow as well as the improvement of energetic performance of the vehicle. Due to the limitations of available energy storage systems in capacity, electrical vehicles need to be recharged repeatedly throughout the day. These charging times represent the major element of down-time for public transport vehicles. Down-time can be reduced by synchronizing charging times with already occurring standstill periods (traffic signals, regular stops and rest periods of drivers).

**Approach - Simulation-based planning utilizing traffic-, energy-consumption-models and empirical data**
The evaluation of the application of novel energy-supplies and drive concepts requires a tool that combines several systems and aspects. These include transportation scheduling, the influence of and the interaction with general traffic and also kinematic models. Such a tool may utilize simulated traffic scenarios based on circulation-data of traffic and public transport. The open source software SUMO (Simulation of Urban Mobility) from the German Aerospace Centre (DLR) can be applied [2]. As for the kinematic model, each vehicle can be simplified as a mass point. It possesses a varying amount of rotational, kinetic and potential energy. For the amount of energy needed to cover a specific distance, driving resistances need to be considered as well as specific efficiencies in the powertrain and the power consumption of different vehicle systems. Real operational data from vehicles that are currently in service allows appropriate model calibration.

**Application – Operational planning for the introduction of inductively charged buses**
In Brunswick (Germany), the line M19 was taken into consideration for the electrification with inductively charged buses [1]. With inductive charging the charging-process can be initiated automatically without a physical connection to the infrastructure. It therefore decreases the time needed for charging, relieves the driver of any necessary actions and does not obstruct passenger service. For the project, it had to be proven though, whether the vehicle batteries could last for a whole route-cycle with varying passenger occupancy and traffic conditions. Other questions were, if charging periods could be integrated into regular driving schedules and if two optimal positions could be found for additional charging periods on the line run. The simulation-based approach could find answers to all these questions. The simulation clearly showed that not only varying traffic conditions have to be reflected, but also the passenger occupancy. The energy consumption of a single drive-cycle varies by about 20 % for the measured cycles and might vary by about 40 % in for theoretical passenger rates. The capacity of available batteries proved sufficient, though. The project proves that results of traffic flow simulations with an integrated energy consumption model are useful for operational planning prior to the start of operation of busses with alternative power trains (full electric, hybrid, conventional).

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