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Coaches as a part of the *eHighway* system: A feasibility study

Kevin Rolko[1], Manfred Boltze, Regina Linke

[1] *Kevin Rolko (corresponding author), rolko@verkehr.tu-darmstadt.de*

All authors: Institute for Transport Planning and Traffic Engineering, Technische Universität Darmstadt, Otto-Berndt-Strasse 2, 64287 Darmstadt

Summary

The awareness in Germany for the impacts of road traffic on human health and the environment has significantly increased during the last few years. For that reason, HEAG mobilo, one of the leading mobility service providers in the German state of Hesse, plans to replace their entire conventional bus fleet with electric vehicles to improve the quality of life in and around Darmstadt. Suitable electric busses for inner-city lines already exist. However, the *AirLiner* is a special case: connecting the city center of Darmstadt with Frankfurt Airport, the *AirLiner* is operated with coaches instead of regular public transport busses using the Federal Highway A5. On that section, a test track for the *eHighway* system has been built in 2018. As busses used for long-distance travel are potential candidates to use the eHighway system, it appears to be an obvious choice to equip an *AirLiner* coach with an electric drive and all components necessary to use the eHighway test track for charging. The findings of a simulation-based feasibility study are thus subject of this contribution.

1 Research Questions

The research project *AMPEAir* was conducted by the *Institute of Transport Planning and Traffic Engineering* of *Technische Universität Darmstadt*, *Siemens AG* and *HEAG mobilo GmbH*, one of the leading mobility service providers in the German Federal State of Hesse.

The first aim of the study was an assessment of the feasibility of equipping a coach (the *AirLiner*) with all required components from a technical point of view to use the *eHighway* test track built on the German Federal Highway A5. The *AirLiner* connects the city centre of Darmstadt with Frankfurt Airport 39 times a day. Secondly, necessary legal issues were analysed by Dieter Posch of Posch Rechtsanwälte to proof the feasibility from a legal point of view. Here, existing concerns regarding the necessity of a second plan approval process could be dispelled. Thirdly, a simulation study based on the existing bus line schedule was conducted with the aim of deriving necessary technical requirements like battery capacity or maximum allowable consumption rates of electric energy as well as testing basic assumptions.

The simulation study and results will be covered in this contribution.

2 Methodology

As a first step, an exemplary reference bus had to be identified in order to be used as a conversion in the context of the *eHighway* system. To achieve this aim, basic requirements from an operational as well as a technical point of view were defined. A document review of existing bus types was conducted and based on the findings, a reference bus was chosen by comparing the attributes of each bus with the requirement set.

In conjunction with the *AirLiner* bus line schedules (and thus the routes and stops served in reality) a preliminary estimation on necessary battery capacities was carried out as a second step. Moreover, the location of an additional charging station was chosen by using the findings from earlier steps of this work.

As a third step, a simulation model was developed to further improve the estimation on battery capacities and consumption rates. For model development, the commercial suite *AnyLogic* was used [2]. The agent-based simulation approach was chosen, which also included discrete and time-based event simulation. In conjunction with a road network model, the *AirLiner* operation was recreated depicting the tours of three busses on a representative day of operation. The interaction between travelled distance, battery state of charge and the actual location of a bus along the road was depicted and analysed, as well. In addition, a graphical user interface was created for the simulation model to visualize the results of each model run and to enable a user to convieniently change parameter settings.

As a fourth and final step and based on the model and the reference bus, three simulation scenarios were defined to depict a worst case, a best case and a probable scenario regarding different consumption rates, battery capacities and charging rates under the *eHighway* test track and the loading station.

3 Results

The feasibility study provided many interesting results. The main result of the first step of work is the reference bus: the *Scania Interlink LD*. The reference bus in *eHighway* configuration will have three battery packs with a net capacity of 30 kWh. This will enable the bus to travel approximately 20 km, consuming 1.5 kWh per kilometre (including air-conditioning).

The additional charging station will be located at the stop Congress Centre Darmstadt. The maximum charging power will be up to 300 kW. The suggested layout and the conditions on the spot are illustrated in Figure 1.

Figure 1: Stop at Congress Centre Darmstadt and layout of the charging station
(Source: [1])

An important underlying assumption concerning the vehicle driving mode should be mentioned before the results of the simulation study are presented. As a priority, an electric vehicle operation should be enabled in densely populated areas, e.g. in the city centre of Darmstadt as well as at Frankfurt Airport. Therefore, in the simulation model, virtual city borders were defined, and each vehicle switches its current driving mode accordingly: a bus leaving one of the pre-defined urban areas switches to diesel engine mode while a bus entering the city borders switches to battery engine mode, if possible. This logic can also be switched off by the user of the simulation model to allow for a calculation of a maximum electric mileage. Hence, the results that will be shown are labelled “fix” switch borders and “variable” switch borders.

The two defined scenarios for the developed simulation model with their corresponding parameter values are depicted in Table 1. A third scenario was also defined and simulated as a worst case. However, as assumptions for that scenario (consumption rate of 2.0 kWh/km for traction and air-conditioning/heating, net battery capacity 18 kWh) proved to be very unlikely, thus they are not presented here.

	Base Case	Best Case
Charging power surplus: Loading station	120 kW/h	120 kW/h
Charging power surplus: Test track	120 kW/h	120 kW/h
Time under catenary (per direction)	3,8 min	3,8 min
Battery capacity (gross/net)	50/30 kWh	50/30 kWh
Consumption rate: air-conditioning/heating	0,75 kWh/km	0,5 kWh/km
Consumption rate: traction	0,75 kWh/km	0,5 kWh/km

Table 1: Parameters of the two main simulation scenarios (Source: [1]).

The most important result is that a partially electric operation of the *AirLiner* is possible under the base case as well as the best case assumptions. This is valid for both variable and fixed city borders. Thus, the emphasis is laid on variable city borders as the electric mileage will be higher.

In the base case, a total of 960 kilometres can be driven in an electric mode, which is about 41 % of the entire distance of 2315 kilometres driven by the bus fleet of three buses in one day of operation. In the best case, the share rises to 78% to approximately 1800 kilometres per day of operation. As expected, an electric operation in the inner city areas will not be possible under the worst case assumptions.

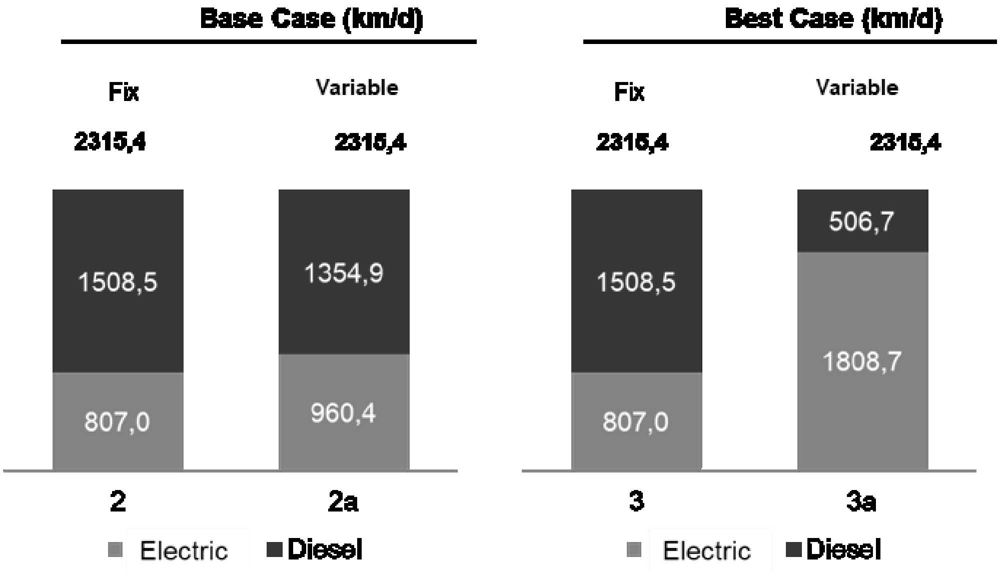

Figure 2: Daily kilometers driven by the three busses in the best and base case scenario with fix and variable switch between driving modes.
(Source: [1])

Finally, it should be mentioned that the *AirLiner* is a proxy only. If the AirLiner, as a coach, can be electrified using the *eHighway* system, than all long distance coaches in Germany could potentially be equipped with necessary components to allow for an electric line operation. In conjunction with trucks for freight transport, the cost-benefit ratio to equip highways with ERS components could be further increased.

The final contribution will cover more details on the simulation models as well as other results.

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