Journey Models for Electric Road Freight Operations

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Abstract

Electrification of road freight is of key importance to meet net zero goals, as it accounts for around 53% of all global trade transport. With rapid electrification of heavy goods vehicles (HGVs), there will be a shift in logistics and operations. This shift depends on what technology is used, which is difficult to predict given the wide range of options available. Currently, the global trucking industry uses only one type of truck, which is a diesel truck. This gives benefits of scale economics and technology sharing. However, electric road freight can be implemented in several ways, which could be fast charging, electric road systems (ERS), hybrid range extenders, battery swapping or 'pony express', where the tractor unit is swapped.

Past studies have shown economic advantages and disadvantages of all these electrification strategies. However, it is unclear how they would interact with each other, and more importantly, which strategy works best for what type of journey. The proposed work aims to answer this question by designing a parametric journey model, shown in Fig. 1, that can compare the cost, emissions and efficiency of all electrification strategies on a single journey. The model takes as input the details of the journey such as journey length, time, stop locations and durations and variables such as charging power if the stops have chargers. The other variables needed include the battery size of the vehicle, road gradient and energy consumption of the vehicle. Using this data, the model can calculate the total cost, emissions and number of vehicles required for the journey.

The cost of the journey is represented in terms of the running cost, which depends on the electricity price of the charging infrastructure used, and the journey income, which depends on the number of journeys possible per truck, or the number of vehicles required to make one journey. The number of journeys possible and the vehicle cost both depend on vehicle parameters such as battery size per vehicle, payload loss, and the number of batteries or tractors required in the battery swapping and pony express scenarios. The journey cost model can then be combined with individual economic models for charging infrastructure such as ERS and fast chargers presented in past studies, which would give an overall cost for a certain parameterised journey.

Preliminary results from analysing high-capacity or 'fast' chargers in this way resulted in the following observations:

1. Splitting fewer longer charging stops (45 min every 4h 30m) into multiple smaller duration stops (30 min every 2h 15m) results in a reduced battery size requirement by around 45%.
2. High-capacity chargers result in a significant reduction in battery size requirements for long-distance electric HGV journeys, but not for short-distance journeys with frequent or longer stops.

3. High-capacity chargers are as economically feasible as low-capacity ones for small stop durations of around 20 min because they have similar break-even periods given the same usage.
4. For long-distance journeys in sparse geographies, static charging needs to be supplemented by dynamic on-road charging.

Similar insights can be drawn in a quantitative way for comparing all the scenarios. The parametric journey model can be used in conjunction with network-level models such as agent-based models to analyse an entire network, as variables like charger demand will depend on the total number of vehicles in the network. Furthermore, probabilistic variables can be added to the model to account for changing conditions such as traffic and incidents.

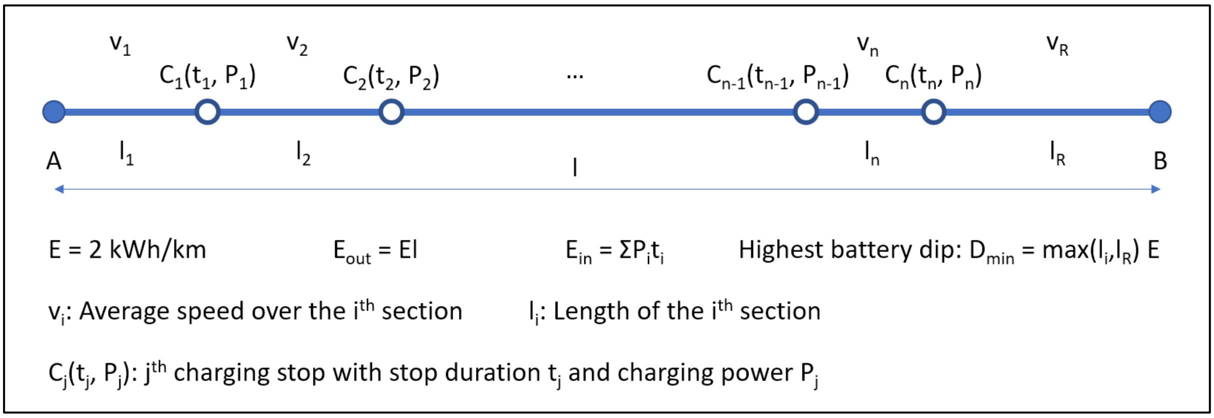

Fig. 1: Simplified Journey Model.

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