On the cost-benefit of a state-road charging system

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Abstract

The greenhouse gas emissions from cars amounts to approximately 13% of the total emissions in Denmark. The green transition of cars is therefore an important step on the way towards carbon neutrality.

However, an increasing number of electric vehicles (EVs) require the corresponding charging infrastructure to be further developed to avoid unnecessary charging congestion. In this paper we examine the societal cost-benefit of charging infrastructure investments for the Danish State Road system by measuring waiting time savings resulting from increased capacity and compare these with the cost of the increased capacity.

The specific aim of the paper is to investigate the requirement for a Danish national road charging infrastructure in different future settings and for different technical assumptions. The model approach is based on a large-scale simulation framework (Vandet and Rich, 2021), which cover the entire Danish national road system and further represent traffic to and from neighbouring countries. Novel optimisation methods are applied to estimate optimal charging requirements and information technologies are introduced as a mean to balance utilisation. The calculation of waiting time is formed through interactions between a generalized queuing system and a model of charging demand in space and time based on random utility maximisation.

Our simulation study is based on the existence of an artificial information-sharing system which inform users about waiting time in the system. The information-sharing is based on feeding information from the queuing system to the users and by using a simple look-ahead predicting of the waiting time. This construction is considered realistic for a 2030 scenario and have several desirable effects: i) it introduce a self-organisation principle where agents tend to circumvent queuing by postponing charging situations when congestion exist, ii) it thereby render a more uniform utilisation pattern across stations, and iii) reduced the required capacity compared to a situation where no information is shared.

The study show that the choice of performance measure is critical. A level of service measured according to average waiting time is very different from a level of service measured according to maximum waiting time or the 99% percentile of maximum waiting time. Hence, with respect to investing in charging infrastructure, it is to some extent a political decision if the infrastructure should support a good level of service 'on average' or be able to service 'more extreme days' as well. Based on simulation experiments, it is found that a level of service measure of 10 minutes of maximum waiting time is likely a good performance measure although an even better indicator is the 99% percentile of the maximum waiting time. It guarantees that 99% of EVs will have a waiting time below 10 minutes and eliminate undesirable extreme cases that may result from a maximum

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guarantee. It is demonstrated that the infrastructure that supports a maximum waiting time of 10 minutes is efficient from a cost-benefit perspective.

The study also indicate that the future demand of charging on the national road system is indeed uncertain. Partly because of uncertainties in the vehicle stock, partly because of technological uncertainties as well as uncertainties with respect to the use pattern. It is thereby important that decisions with respect to investments acknowledge this uncertainty and develop solutions that are robust across a range of different scenarios.