PLANNING CHARGING INFRASTRUCTURE DEPLOYMENT: A NEW SPATIO-TEMPORAL MODEL

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Overview

The environmental objectives set by the various international summits call for greening the transportation sector, which is responsible for a significant share of greenhouse gas emissions. The current trend is a transition from the current fleet of vehicles to a fleet of electric vehicles. To allow this transition, it is necessary to ensure the acceptance of the electric vehicle among its users. This acceptance requires the deployment of a charging infrastructure adapted to user needs. In this study, we propose a multi-criteria charging infrastructure deployment model, not only geographically but also temporally, in order to accompany this transition. The model is oriented to meet the needs of users, assuming that charging demand will follow if a suitable infrastructure is proposed. We then conduct a comparison study between the new model and the classic deployment models found in the literature.

Introduction

The current climate issue requires a drastic reduction in anthropogenic greenhouse gas emissions. Among the highest emitting sectors, road transport accounts for between 20 and 25% of these emissions in Europe and the US [1]. A transition in this sector towards greener mobility is therefore an important lever to reducing global greenhouse gas emissions. The solution currently at work is to transform the fleet of internal combustion vehicles into a fleet of electric vehicles, with much lower emissions [2]. Such a transformation cannot take place without the acceptance of electric vehicles by users. To achieve this user acceptance, electric vehicles must be as convenient as internal combustion vehicles in their daily use, including for those who cannot charge their vehicle at home. An important step required to achieve this goal is the existence of a charging infrastructure adapted to the needs of vehicle users [3]. But due to the high cost of deploying such an infrastructure, it cannot be a prerequisite for the pre-eminence of electric vehicles in the fleet on the road : the infrastructure cannot precede the democratization of electric vehicles, but must accompany it [4]. However, the existing literature focuses on the final optimality of the charging infrastructure, without taking into account its development according to a temporal pattern consistent with user needs. This risks slowing down the adoption of electric vehicles, and therefore investment in the charging infrastructure, which may never exist in its final version because of this vicious circle [5].

We propose in this paper an infrastructure deployment model centered on user needs, considering the integration of both spatial (where to place the charging stations) and temporal (in what order to place them) aspects in charging infrastructure deployment. The objective of the analysis of this model is to obtain the charging infrastructure that offers the best possible service to users. Charging vehicles should be as easy as possible for users, who should be able to use their vehicles without having to worry about its autonomy or the time it will take to charge it.

Methods

We employ an iterative approach. First, candidate sites are selected, on which it will be decided whether or not to place a station, and which type of station to place (fast, medium, slow). This pre-selection is not necessary, but limiting the number of potential sites reduces the complexity of the problem, and main locations at which charging events are likely to occur are identifiables [6]. Once these sites are selected, we determine the usefulness of placing one or more stations at each of them according to user preferences and resource allocation efficiency. This usefulness is determined by the charging opportunities offered to users at that site, so that they do not feel the charge as a constraint in the use of their electric vehicle. We determine the utility of a site according to the following criteria:

• **The demand for parking on the site**. The more vehicles park at a location, the more useful it will be to put a station there. The number of distinct vehicles is also considered, in order to serve a maximum number of users.

• **The parking duration on the site.** It allows to determine which type of station to put at this location, adapting the necessary charging time to the parking time. For example, if a vehicle is parked for three hours, it is inefficient to install a more expensive station that will charge it in twenty minutes, since the vehicle will unnecessarily occupy the charger for the remaining time.

• **The state of charge of the vehicles on the site**. Except for a few special cases, the less charged the battery of vehicles arriving at the site, the more useful it is for them to be able to recharge.

• **The area coverage**. There must be as few white zones as possible, otherwise users will not have confidence in their electric vehicle, which will remain a second car.

Based on these criteria, a score is calculated for each one of the candidate locations. The principle is then quite intuitive: the first station is placed on the location with the highest score, then the scores of all the sites are recalculated, as these may have changed with the addition of a station on the territory (for example, the state of charge of vehicles may have changed at some locations). The new site with the highest score is then selected, and so on. It is important to note that a site where a station has already been placed is not disqualified for a second station: its score is simply modified, in particular because of the territorial coverage criterion which favours the spreading of stations over the territory.

By doing so, the stations are placed where they are the most useful, following a consistent time pattern. This model also allows for the direct integration of already existing infrastructure, including private facilities, since it is based mainly on criteria related to vehicles.

First results and work in progress

Our first results, obtained by multi agent simulation from MATSim [7], do not yet include the state of charge of the vehicles. They suggest that the model behaves as expected: it places the stations where the most cars are parked, and selects stations allowing a faster charging when the vehicle parking time is reduced. Moreover, a small change in vehicle behavior does not result in a change in the entire charging infrastructure, which is reassuring for the robustness of the model. Compared to a station placement according to a classical Set Coverage Location Model [8], it seems in most cases to shorten travel times, as charging is integrated during users' other activities. The next step of the work is to integrate an overall optimum into this model. Indeed, a purely iterative placement of the stations means that the first stations are placed without taking into account the following ones. This gives a necessarily sub-optimal result for the final infrastructure. This optimum will determine the final infrastructure, and the deployment schedule will then be iterative. The complexity of the optimum lies in the integration of the state of charge of the batteries, which depends on the charging stations in place as well as on the users' routes. The optimum will be then compared to the result obtained with the purely incremental method.

Conclusions

We developed a model for the placement of charging stations for electric vehicles that focuses on user behavior, so that the charging of their vehicle is integrated into their daily life. This model allows us to make a spatio-temporal planning of the deployment of a recharging infrastructure, in order to accompany the democratization of electric vehicles. We thereafter want to investigate the effects of this deployment method on the adoption of electric vehicles.

References

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