DESIGN OF SERVICE UNIFYING INFRASTRUCTURE FOR CHARGING OF ELECTRIC VEHICLES

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Abstract
The article focuses on the future growth of electric vehicles on our roads. As the number of electric vehicles gradually increases, it is necessary to ensure sufficient charging infrastructure. The topic elaborates the design of a service unifying the charging infrastructure for electric vehicles in individual passenger transport, develops the design of the service embedded in a real environment and describes its functioning. The charging infrastructure needs in the capital city of Prague were identified.

Key words: *electromobility, charging station, digital services.*

INTRODUCTION
More than half of the world's population lives in cities. They are, and have historically been, the sites of significant cultural, political and technological change. Cities are at the heart of the world's economy, accounting for more than 80% of total gross domestic product. By 2030, up to one billion more people are expected to live in cities (*Bouton et al., 2017*). This growth will place increased demands on the provision of logistics in cities. The transport of goods and food-in will place greater demands on the efficiency of freight transport. Further development of public transport will be important for passenger transport. Equally important will be individual passenger transport. Leaving aside walking as the most widespread mode of individual transport, the most widespread mode of transport today is the car. The trend today is to use other modes of individual transport. It is not only in countries like the Netherlands that people are starting to use bicycles more for transport (*Walking and cycling as transport modes, 2020*). The use of bicycles, both private and shared, is on the rise. Other means of micro-mobility, such as electric scooters or electric scooters, especially in the form of shared facilities, are also growing in popularity (*Heineke et al., 2019*). Passenger cars are also moving from internal combustion engines to hybrid and pure electric drives. Currently, the share of electric passenger cars in the total fleet in the European Union is around 2%. By 2030, the share of electric passenger cars in the total fleet is projected to increase to 23%. Western countries such as Germany, the Netherlands and France will be the main contributors to this increase. In other countries, the increase in the number of EVs will not be as steep and fleet renewal will be slower (*Niestadt a Bjørnåvold 2019*). The aim of this study is to design charging infrastructure for electric vehicles.

MATERIALS AND METHODS
Service design to unify the infrastructure
In order to meet the demand for charging, additional charging stations will need to be built in the future. This study develops a proposal for the operation of a mobility centre service and station that will provide a unified experience for EV owners, car share users and public transport passengers. The biggest benefit for users from all groups is the possibility to find all the services they need in one place and to choose the most appropriate mode of transport for the moment.
Design of the charging station - Mobility hub distribution
The basic criterion for the location of mobility nodes is the demand for charging infrastructure or the demand for modal shift. Other criteria for station location are technical requirements for construction. If the charging stations are for electric and hybrid vehicles, the location of the stations will be most

appropriate near or within existing parking lots. Suitable P+R car parks are those located on the outskirts of the city with good public transport accessibility. Vehicles usually spend several hours in these types of car parks, so that a large number of fast charging stations are not needed for charging. The opposite situation occurs in car parks located close to the city centre. Due to higher parking prices and lower capacity, people leave their vehicles in these types of car parks for shorter periods of time, so the need for fast charging stations will be higher. For charging micro-mobility vehicles, a location is defined by the number of people moving around the location and transferring to another means of transport. Within the periphery, the demand for micromobility is different than in the city centre.
According to the different demands, the stations were divided into the following types: central, urban, peripheral, suburban (Table 1).

Tab. 1 Types of stations

Central	vehicle charging, shared micro-mobility facilities, transfer to public transport, additional services
Urban	shared micro-mobility facilities, transfer to public transport, limited vehicle charging
Peripheral	vehicle charging, transfer to public transport, P+R parking, limited shared micromobility facilities
Suburban	vehicle charging, transfer to public transport, P+R parking

The Figure 1 shows the possible location of stations within Prague and the distribution by type.

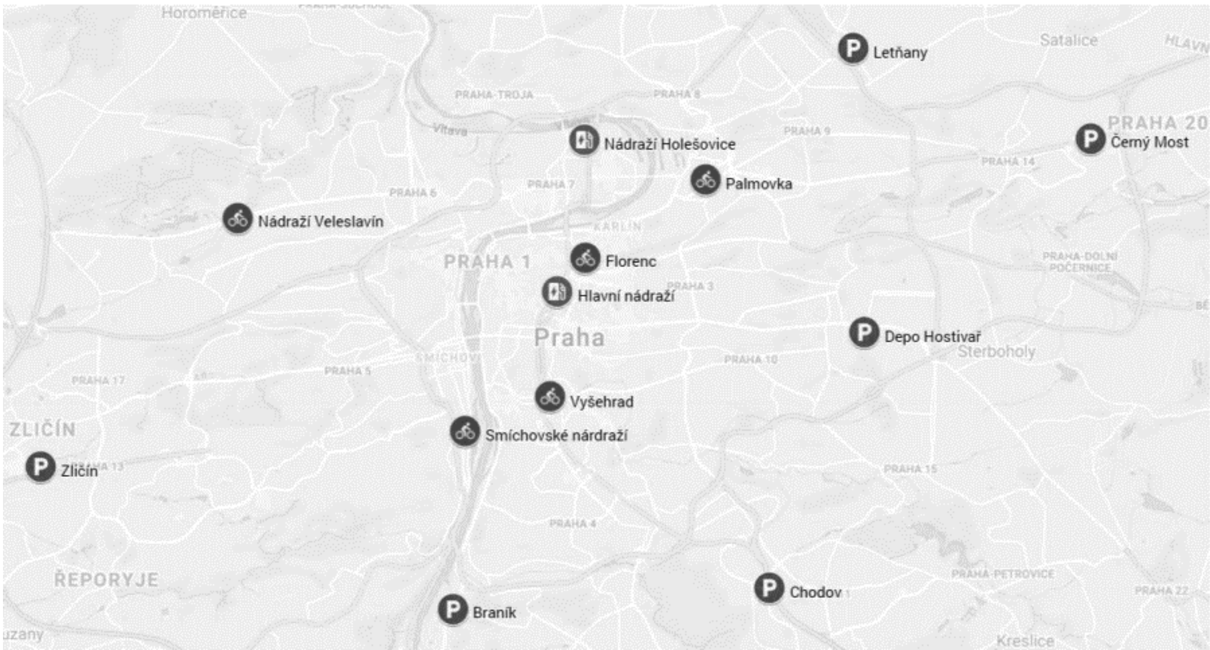

Fig. 1 Map of station locations in Prague

A central type of station, located for example at the Main Railway Station or Nádraží Holešovice. Location with high turnover of people, central location in the city and good accessibility by car. The development of the station is possible due to good electrical infrastructure (proximity to the station) and sufficient number of parking spaces for cars. Suitable for building a large number of DC fast charging stations and standard AC charging stations. Central location advantageous for the use of micro-mobility. Possibility to transfer to public transport.

Urban-type stations (Florenc, Palmovka, Vyšehrad, Smíchovské nádraží, Nádraží Veleslavín) are characterised by a high turnover of people transferring between means of transport. Suitable prerequisite for micromobility and other shared services. Due to the lack of parking space for a large number of vehicles, only a few fast charging stations should be built.

Peripheral type stations (Letňany, Černý Most, Depo Hostivař, Chodov, Braník, Zličín) located within P+R car parks. The car parks are directly connected to public transport, in most cases to the metro. Due to the distance from the city centre, it is not entirely advantageous to build for micro-mobiles or only for electric scooters, which are able to travel at lower speeds.

The suburban type of station (Neratovice, Brandýs nad Labem, Říčany, Beroun, Kladno), which is located in the cities adjacent to Prague. It is most often located near the train station, where people park their cars and change to public transport. AC charging stations are suitable in this solution. If there is a shared transport system in the city, it is advisable to have a station directly at the station.

RESULTS AND DISCUSSION

Nowadays, each type of vehicle has its own specifics, different uses and different vehicle care needs. Therefore, for an inexperienced user, it is not entirely straightforward how to charge or use a given type of vehicle. Hence the myths surrounding electric vehicles and the emergence of die-hard fans or opponents of electric vehicles. In future, it would be very useful to establish standards that would ensure carefree operation for users and operators of these vehicles.

The biggest obstacle to the development of charging infrastructure is the financing of its construction. This is also the case for the proposed mobility hubs. The purchase costs of individual hardware elements of the stations are in the hundreds of thousands of crowns. The cost of one 50 kW DC station is approximately CZK 500 000, while the previously proposed mobility hub at the Main Station would accommodate ten such stations. AC charging stations are cheaper, but the cost is still around CZK 100 000 per station. Other necessary equipment and building modifications, such as bringing in sufficient power, battery stations, transformers, solar panels, software or identification and communication equipment, are also expensive. Building a single mobility center can cost tens to hundreds of millions of crowns (*Nelder a Rogers, 2019*).

In terms of charging station requirements, it is advisable to locate them close to or preferably directly in larger P+R parking areas. Here, vehicles are usually parked all day and can therefore be recharged throughout this time. The second type is vehicles that arrive directly in the city center, where they usually do not spend long hours but only minutes. According to this logic, it is possible to use different types of chargers with different values of charging currents and thus different time required to charge the vehicles, as described by (*Bräunl et al., 2020*). In this comparison, it is necessary to include the possibilities and methods of charging public transport vehicles, which are directly linked to the individual transport segment. Whether by car, bicycle or other modes. Buses often have to be operated for hours a day and therefore different ways of charging them arise. Such as, recharging at certain stops or changing individual batteries, which on average takes 8-10 minutes (*Li, 2016*).

For specific use, the city was divided into 4 areas. Namely, centre, urban area, periphery and extra-urban area (Table 1). In the centre, it is advisable to build a large number of fast-charging DC stations, as well as standard AC stations with less power. Here the use of micro-mobility and a large possibility of transfer to public transport is appropriate. A similar mode of transport is in the urban type, where there is a greater possibility of using shared transport services. In the peripheral type of transport there is a high concentration of vehicles that remain parked in so-called P+R car parks, where each car park is connected to the public transport network. Here there is a need for charging stations, but it is possible to use slower AC types. The last type is suburban, where people travel mostly for work and the commuting distance is greater. These problems are addressed in the study (*Sheppard et al., 2016*), where they are tackling the issue of electric vehicles in Delhi. Delhi, which has a population of just under 19 million, is considering setting up 2,764 charging stations for the expected number of hybrid and electric vehicles in operation. The infrastructure of charging stations in such a large city is complex, not just in terms of installation but in terms of its quality of deployment. India projects that over 6 million electric vehicles should be on its roads in the coming years.

CONCLUSIONS

The size and technical level of the charging infrastructure depends on the number of electric vehicles. In general, charging infrastructure should be as user-friendly and accessible as possible. However, the design of the infrastructure may be quite different if the actual number of vehicles differs significantly from the values assumed in this document and exceeds the number of PHEVs. In addition, regulations that would, for example, prohibit vehicles from entering city centers may also have an impact.
The solutions for a large-scale EV charging system are divided into 4 types. These are the center, the urban area, the periphery and the non-urban area. In relation to the charging points, it is necessary to solve the problem of the continuity of individual transport and public transport. This issue is strongly linked to the high input costs and electricity connection.

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