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Battery Swap Station Location Problem for Electric Vehicles

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Abstract

Increasing environmental awareness has led to the wide use of electric vehicles. Due to the low energy density, batteries in electric vehicles must be frequently switched. Therefore, the battery swap station location problem, which determines the number, location, and size of battery swap stations, is vital to the operations of electric vehicles. The battery swap station location problem may be examined from different viewpoints according to whether the stations are operated by the government, by a private firm, or by several private firms. Hopefully, more future research efforts would be directed to this practical new problem.

Keywords: Electric vehicles; Battery swap station location problem; Facility location; Transportation

During the last few decades, environmental impact of the petroleum-based transportation infrastructure has led to the wide use of electric vehicles. In contrast to fossil fuel-powered vehicles, the electricity consumed by electric vehicles can be generated from a wide range of sources, including nuclear power and renewable sources such as tidal power, solar power, and wind power. Electric vehicles have drawn much attention from the research world and the auto manufacturing industry. Electric vehicles are also extensively used in many cities in the world.

One type of electric vehicles use batteries as the rechargeable onboard electrical storage medium. These batteries have to be switched at battery swap stations when the electricity is to be used up. A new, fully charged battery will be stored on the electric vehicle to provide electricity. The time for switching batteries is much shorter than the charging time by direct connection to generation plants. However, due to the low energy density of batteries compared to the fuel of internal combustion engined vehicles, batteries in electric vehicles must be frequently switched, normally three to four times a day for an electric taxi. Therefore, the availability of battery swap stations are vital to the operations of electric vehicle. For instance, the routing of one or a few vehicles to transport given cargo at minimum cost [1], may need to incorporate the sojourn points for switching batteries.

The battery swap station location problem, which aims to determine the number, location, and size of battery swap stations in a city, a region, or a country, is thus an important research direction along with the technological development of batteries. The battery swap station location decisions depend on the current number of electric vehicles, and affect the future number of electric vehicles as a higher service level provided by battery swap stations would stimulate the use of more electric vehicles. Therefore, the battery swap station location problem can be considered as a facility location problem with elastic demand [2]. If the government is operating the stations, the objective should be to maximize the social benefit. The social benefit may include the reduced cost of the electric vehicle users and the benefit from less pollution. If the battery swap stations are operated by a private firm, the objective would be to maximize the total profit. A more complicated case would be that several private firms operate battery swap stations and compete with each other. Game theoretical models combining optimization theory must be developed to account for the market equilibrium between each of the private firms and electric vehicle users. Intuition might give wrong conclusions in such a complex context. For example, one may conjecture that if one private firm builds more battery swap stations, the other firms would gain less profit. However, it is possible that the newly built stations lead to a dramatic increase in the number of electric vehicles (depending on the elasticity of the number of electric vehicles with respect to the service level provided by battery swap stations), thus increasing the profit of every private firm [3].

In sum, the battery swap station location problem has significant practical implications and thus is a worthwhile research direction. I am very happy to see that the journal Advances in Automobile Engineering, published by the OMICS Group, provides an open access platform for discussions of the topic. Hopefully, more and more researchers from various disciplines, such as automotive engineering, operations research, business, and transportation engineering, would pay attention to the battery swap station location problem.

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