Utilizing mobility data to facilitate the introduction of E-Taxis in Vienna

Feasibility Study of a Decision Support System for the Introduction of Battery Electric Vehicles as Taxis

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Abstract — **Introducing E-Taxi fleets in urban areas poses a number of economic, organizational and technical challenges related to the nature of Battery Electric Vehicles (BEV). This paper discusses these challenges and demonstrates how existing mobility data can aid the underlying decision process to overcome them. We present an integrated approach developed for the introduction of an E-Taxi system in the city of Vienna, where mobility data based on taxi floating car data (FCD) was used as decision support.**

Keywords: Electric Taxis, Electric Vehicles (BEV), Charging Infrastructure, Energy Consumption, Mobility Data

I. Introduction

The introduction of E-Mobility is a strategic objective in national and international sustainable urban mobility plans (SUMP). Challenges for reaching this goal currently include the high initial costs of BEVs and their limited range. While these challenges currently limit the adoption of electric vehicles in the private sector, the above disadvantages are less pronounced when it comes to operating taxi fleets: The high initial investment costs are reduced by high overall driving performance [1], which is usually common for taxis fleets operating in multiple shifts. But most importantly the driving profile of taxis fits very well to the requirements of electric vehicles: a high number of short trips in combination with breaks at taxi stands (TS) which can be used for recharging the battery.

Replacing conventional taxi fleets with E-Taxis is expected to have a number of positive effects such as reducing emissions and noise or reducing the customer prejudice regarding electric vehicles [1]. However, introducing E-Taxi fleets into urban areas has been met with a number of challenges in practice. Recent work [2] has identified 3 classes of challenges in the decision making process which currently inhibit a more wide-spread adoption of E-Taxi fleets:

- Decisions on electric vehicle operation and charging
- Planning and installation of charging infrastructure
- Decisions concerning innovations in taxi distribution

Our work is based on the assumption that such planning decisions can benefit from increased in-depth knowledge about the mobility patterns and driving behavior of taxis.[3] This paper demonstrates how mobility data analysis was used in an E-Taxi feasibility study for the city of Vienna.

II. Mobility Data Analysis

Our analyses use the taxi floating car data from a taxi operator (Funktaxi 31300) in Vienna. The data set consists of several years of detailed vehicle trajectories from a fleet with about 800 vehicles. The trajectories include GPS position data with timestamps and a status (e.g. “available”, “occupied with customer”, “at taxi stand”, etc.). The data reporting interval varies between 25 to 40 seconds depending on the current taxi status. A sample of typical vehicle trajectories and taxistands are shown in I (left).

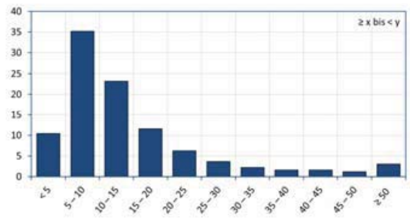
A. Analysis of TaxiDriving Patterns

Analysis of the available trajectories provides detailed insight in taxi driving behavior: the average number of trips per vehicle and day, typical trip distances, the spatiotemporal trip distribution and the average waiting times at taxi stands were reconstructed from the available data.

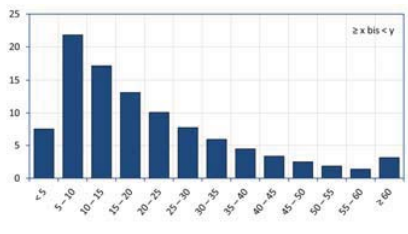
Detailed analysis of taxi trajectories and driving behavior provides valuable input for decision making: When Taxi stands are assumed as possible charging locations, it becomes easy to analyze the typical driving distance between charging opportunities. Fig 2 (top) indicates the relative distribution of trip lengths for trips beginning and ending at a taxi stand. This distribution can for example give valuable insight regarding decisions about vehicle and battery size: the indicators of mean distances (14.2 km), and percentiles, e.g. 0.25 (5.3 km), 0.75 (17.0 km) and 0.9 (31.3 km) are valuable background information.

The scenario of charging at taxi stands can be further refined with detailed knowledge about typical waiting times. Fig. 1 (bottom) represents the relative distribution of waiting times at taxi stands. The arithmetic mean of waiting time is

19.4 minutes, with percentiles, e.g. 0.25 (6.5 min), 0.75 (26.7 min) and 0.9 (42.1 min).



Distances of trips between taxistands [km]



Waiting times at Taxistand [min]

Fig. 1. Relative Distribution of Distances [km] between Taxistands for all Weekdays (top) and Waiting Times [min] at Taxistands for all Weekdays (bottom)

B. *Analysis of Energy Consumption*

In order to accurately estimate the frequency with which an E-Taxi needs to recharge, the expected energy consumption has to be well known. Although energy consumption is strongly dependent on driving distance, it is not a constant value per unit (kWh/100km) but related to velocity, topology, environmental conditions, etc. Therefore we have developed a model to estimate the energy consumption of BEV moving in the city of Vienna. We use a dynamic longitudinal model (DLM) including factors for kinetic energy, potential energy, rolling resistance and air resistance [3]. Additional parameters were estimated from a digital elevation map (slope) and the taxi status (increased mass for vehicle occupied with customer) as well as derived traffic state, number of stops and driving information. The DLM allows to estimate the energy consumption for each taxi journey and enables detailed analyses of the energy requirements of a taxi fleet (e.g. distribution of the energy consumption per trip, overall energy consumption of a taxi fleet, etc.). Further analysis has shown feasibility rates from up to 75 percent depending on empirical taxi data [2].

C. *Scenarios for Infrastructure planning*

To identify possible locations of new charging infrastructure the main influencing factors are the mobility behavior of the taxi fleet and the constraints of the existing energy grid. Based on the mobility pattern of a taxi fleet and additional preconditions by stakeholders and regulations, possible scenarios for infrastructure placement can be evaluated. Fig. 2 (right) shows an example of a spatial analysis. The end positions of customer trips were used to generate a heatmap which indicates the demand for charging stations in the area of Vienna. Using the existing charging infrastructure as an overlay, this approach identifies gaps in the charging infrastructure and helps to avoid bottlenecks and minimize additional journeys for charging.

Fig. 2. Taxi data (left) and an example of a heatmap (rigth) representing the destinations of customer trips merged to clusters

III. CONCLUSION

Introducing E-Taxi fleets in cities creates a number of new challenges for decision making. In this paper we show how careful analysis of existing moblity data can provide valuable input to the decision making process. Table I summarizes different types of challenges and indicates which mobility data analysis techniques can help in resolving these challenges.

TABLE I. E-TAXI CHALLENGES SUPPORTED BY MOBILITY DATA ANALYSIS

E-Taxi Challenges	**Mobility Data Analysis**
Decisions on Electric Vehicles and their Operation and Charging	Taxi and Driving Patterns: Distances and Distribution of Distances, Day-Profiles, Waiting Times, Day-/Order-/ Strategies, Energy Consumption
Planning and Installation of Charging Infrastructure	Energy Consumption: Post Trip, Vehicle Data, Traffic States,.. Infrastructure and Economic Aspects: Location Decision Support, Heatmaps, GIS-Analysis, Major-Road Network (Intersections), Estimated Driving Costs,…
Innovations in Taxi Distribution Systems	Customer Frequencies, GIS-Analysis, “fair distribution”, Routing and Navigation,…

ACKNOWLEDGMENT

The work for this study was done within the Austrian research projects ZENEM and W-eTaxi. The taxi data was provided by taxi 31300 (Taxi 31300 Vermittlungs-GmbH).

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