Proposal for Distinguished Awards for Interdisciplinary Sustainability

Future Vehicle Sharing Service Design for Ann Arbor

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Autonomous electric vehicle (EV) implementation will spark a revolution in transportation systems during the next half-century. As a “green” solution for future transportation planning, it is expected to mitigate environmental impacts, traffic congestion, and parking supply problems, while offering a safe and low-stress transportation solution for customers. One of the promising applications is a vehicle sharing service: once customers request a ride via smart phone, an autonomous EV arrives at their door and transports them to their destination, after which it goes to a charging station, or waits for the next trip while at its current one [1]. The challenge is that a profitable and feasible vehicle sharing service design requires an interdisciplinary approach, integrating *marketing, engineering, and operations*.

This study proposes a future vehicle sharing service design for Ann Arbor. We integrate EV design, charging station design, autonomous transport planning, and service demand forecasting systems, as shown in Fig. 1 (note that red and black letters indicate decision variables and shared responses, respectively). The optimization objective is to maximize some metric – for example, service profit – with respect to design decisions and costs. Modeling plans of sub-design problems are explained as follows.

(1) EV design: This model consists of driver, control unit, motor torque control, battery, inverter, motor, and driving simulation models [2]. We focus on the lithium-ion battery, permanent magnet synchronous motor, and gearing; we then simulate engineering performance levels, which are used as constraints for feasible vehicle design. Range and MPGe, as shared variables, are used for the transport planning model, and range & battery capacity likewise are used for the charging station design model. Similarly, manufacturing and maintenance costs are modeled for profit optimization.

(2) Charging station design: This model maximizes the total EVs flow volume, which can be recharged, and minimizes queuing time and infrastructure cost with respect to the charging station design model. The charging station design model decides the number of charging stations and their location, given vehicle range. Outputs of this model, such as charging station location, capability, and charging time, will be used for the transport planning model. For charging station location modeling, we will modify the flow refueling location model (FRLM) [3], which has been widely used to find the optimal location of

![Fig. 1. Autonomous EV Sharing Service Design Framework](image-url)
refueling facilities for alternative-fuel vehicles with limited range. We will select candidate locations for charging stations for autonomous EVs based on an Ann Arbor network map, and then find optimal locations by the mixed integer linear programing formulation with heuristic algorithm.

(3) Transport planning: This model optimizes the fleet assignment and charging schedule. Customer wait times and operating costs will be estimated with respect to fleet size (i.e., # of vehicles), assignment of fleet, and charging scheduling. For the simulation of this model, we will draw origins and destinations of customers from a defined distribution, and will use real-time state of charge (SOC) of the fleet from driving simulation models. The transport planning model and service demand model are coupled; number of trips for transport planning is given from service demand model, and customer wait time for the demand model is obtained from the transport planning model.

(4) Service demand: This model forecasts consumer demand with respect to service attributes such as fare, wait time, etc. Possible competitors for the vehicle sharing service include personally owned vehicles and public transportation. Choice data are gathered using choice-based conjoint analysis from Ann Arbor citizens. Hierarchical Bayesian estimation [4] will then be used for building a heterogeneous service demand model by considering various choice scenarios.

In summary, this project will propose a profitable future vehicle sharing service for Ann Arbor by considering EV design, charging station design, autonomous transport planning, and marketing strategy. This service will contribute to solving environmental impact, traffic congestion, and parking supply problems in the conventional transportation system. Also, this project can help service designers and policy makers understand the relationship between product, service infrastructure, and consumers. It also makes it possible to identify optimal balance between the design decisions from different disciplines when they are coupled and have tradeoffs. Future transformation systems in Ann Arbor will be more green due to autonomous EV sharing service, and our decision making approach will maximize the utilization of this service through holistic approach. For robust design, we will calculate sensitivities of our solution to changes in input parameters and assumptions.

**Budget and Timeline**

We plan to use $3,000 for the consumer survey; 200 Ann Arbor citizens will receive $15 each for participation. We plan to use $2,000 for undergraduate student support; $10/hour · 10hours/week · 20weeks. Total cost is therefore $5000. Project planning and literature review will take until Feb 28; modeling will take place Mar 1 to July 31; optimization will take place Aug 1 to Sep 30; progress report will be available Oct 1; analysis will take place Oct 1 to Nov 31; and final report will be available Dec 31.

**Reference**


