Multi-Purpose Environmental Monitoring Device

Deciphering Electric Vehicle Adoption: How do Cities Prepare?

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

It cannot be denied that electric vehicles (EVs) are steadily taking over the world of transportation. Once considered unfeasible both practically and economically, EVs have challenged the authority of conventional gasoline vehicles. Tesla, for instance, has climbed to the top of the automotive industry by means of rapid technological innovation, revolutionizing the automobile from its manufacturing process to how it's sold. Modern prominence of EVs has introduced significant shifts into society by shaping economic patterns, reducing carbon emissions, and necessitating infrastructure modifications. Through research on the topic of EVs in the context of Science, Technology, and Society (STS), I aim to answer the following question: How do cities need to modify their infrastructure to accommodate the influx of EVs? The importance of this question stems from the inevitable reality that in the coming years, EVs will replace internal combustion engine vehicles. If, however, cities are unable to construct sufficient charging infrastructure, strengthen power grid resilience, and rethink urban planning strategies while maintaining fairness and equity, then there is little hope for a sustainable future in transportation. Following some brief context, the STS portion of the prospectus will delve deeper into the research question and how it will be answered. It will then identify relevant social groups and discuss the STS framework to be used in analysis. Shifting focus, my technical project is not connected to the proposed STS research topic. I intend to build a compact environmental monitoring device that can track parameters like temperature, humidity, air quality, and UV index. The primary goal of building this product is to enhance human health, safety, and comfort in various environments and potentially integrate with smart home systems.

Technical Project

The central technical feature of my device is real-time environmental data collection and display. Its broader purpose, however, is to provide users with information about their surroundings to make appropriate health, comfort, and safety decisions. The motivation behind this product stems from a personal need to track environmental variables that are hard to predict by eye. As someone who has lived in hot climates, experienced dangerous sun exposure, and dealt with wildfire-fueled air pollution daily, I understand the importance of protecting one's body from environmental hazards. The technical project will be completed through a semester-long capstone course in the spring of 2024. It will consist of three distinct steps: designing the printed circuit board (PCB) and assembling all hardware, developing software for data retrieval and display, and finally calibrating the system through tests.

Hardware-wise, it will be necessary to first design circuitry in NI Multisim that integrates an OLED display, appropriately selected sensors, and the TI MSP432 microcontroller (depending on resources and time, a Wi-Fi module might be installed as well to enable wireless transmission of data). A total of four distinct sensors will be needed, each recording one of the listed environmental parameters. A power supply will then be integrated into this circuit in the form of a rechargeable battery and voltage regulator. Next, the resulting schematic will be transferred into an Ultiboard layout and connections will be routed. Once the board is assembled by a local manufacturer, a robust casing will be designed using computer-aided software and 3D printed. This feature will protect the embedded hardware from any external damage.

In terms of software, the MSP432 microcontroller will be programmed using the C programming language. The code's primary purpose will be to efficiently acquire and preprocess sensor data while constantly checking for errors or irregularities. It will also serve to display this filtered data onto an OLED screen using a simple user interface.

Throughout the engineering design process, individual sub-systems will be consistently tested and calibrated to avoid any irreversible mistakes early in the project. This will ensure that users don’t experience issues when examining their environmental parameters, no matter the conditions.

STS Project

To answer how cities will need to adapt to handle the surge of EVs, I must first pinpoint which elements of urban infrastructure might need modifications and what the potential consequences are if changes aren’t made. First and foremost, EVs require functional charging stations. This necessitates substantial investment from both governments and automotive companies. McKinsey & Company estimate that through 2030, approximately “1.2 million chargers will be needed for public use cases” and that “hardware, planning, and installation for public charging could cost more than $35 billion.” (Kampshoff, 2022) Without this investment, existing stations could become overloaded, opportunities for economic growth could be missed, and general EV adoption could stagnate, resulting in more reliance on combustion vehicles. Additionally, the adoption of EVs will require strengthening of the electric grid. ABI Research highlights that a household replacement of two combustion vehicles with EVs can increase daily energy consumption by nearly 74% (Hodgson, 2023). This degree of power grid stress is not sustainable. While long-term solutions exist, the true challenge lies in finding an answer to the energy problem sooner rather than later. Finally, cities must determine how to integrate charging infrastructure into new residential and commercial areas, along with managing traffic flow on busy roads to prevent congestion and maintain efficient access to charging stations (Wang et al., 2021).

Answering the central research question requires a multifaceted approach. To achieve a holistic answer, the first sub-question I must address concerns optimal charging infrastructure. This requires an in-depth understanding of charging station types, costs, and ideal locations. The primary sources that I will use to gather information on this sub-topic include research publications and prediction models. Some research findings, for example, argue that charging time is the most critical factor in reducing infrastructure costs, whereas increasing the number of charging stations has only marginal benefits (Zhang et al., 2013). Should governments then install fewer super-chargers or more regular ones? A separate publication generates a model that can help urban planners decide where to place charging points based on utilization likeliness (Wagner et al., 2014). However, is this the best parameter to use when deciding the spatial distribution of stations, or might it fuel inequity given that current placements are heavily skewed against low-income neighborhoods (Khan et al., 2022)? Building the right charging infrastructure isn't straightforward and includes many variables that must be wholly understood.

The second sub-question I intend to answer pertains to smart power grid management. I will first investigate empirical datasets and pre-trained simulations to quantify the additional load EVs will place on the grid. Software for this task has already been developed by researchers at Cornell University (Ahourai et al., 2013). Then, I aim to gain insight into management strategies capable of reducing this stress using research articles. Garwa et al. (2019), for instance, provide a technical lens into how different charging methodologies can minimize the adverse effects of EV fueling. It will also be important to evaluate the feasibility of power grid upgrades, especially given the task's cost and complexity. In the 2019 edition of the IEEE Electrification Magazine, Coignard et al. (2019) not only analyze the electrical load demand as a function of time throughout a given day but also estimate the capital costs for a variety of grid reinforcement components. Research into pieces like these will allow me to better understand how cities can respond to the increased demand in energy caused by EVs.

Finally, the third sub-question I need to address relates to the government's role in incentivizing continued EV adoption and crafting infrastructure-related legislation. Research in this area will prioritize research articles and publications by federal executive departments. While it's true that EV sales are expected to rise in coming years, more widespread adoption is paramount in both rationalizing and supporting infrastructure investments. Langbroek et al. (2016) analyze the effectiveness of various policy incentives on EV adoption, finding that incentives have positive effects but don't necessarily have to be financial. Things like free parking or access to bus lanes can be equally effective. I also intend to estimate whether increased EV adoption by city residents can overcome the associated infrastructure costs. With additional EV-owners on the road, car manufacturers, for instance, might have more reason and resources to fund charging station installations in cities. The Conference Board, however, argues that "federal fuel tax revenues could decline by nearly 60 percent if passenger and truck electric vehicle sales made up 100 percent of new annual vehicle sales by 2040." (Heil, 2023) There are concerns that this could in turn worsen other elements of transportation infrastructure provided the drop in revenue. On a separate note, governments will also have the responsibility of designing charging station regulations. I hope to identify the best design standards policymakers and engineers can implement that consider the needs of individuals with disabilities. The U.S. Access Board, for example, provides an in-depth list of design recommendations for accessible

EV charging stations, discussing both mobility and communication features (U.S. Access Board, 2023).

Policymakers, automobile manufacturers, EV owners, and non-EV owners are the relevant social groups I will consider for my STS project. Policymakers can be narrowed down to local government officials who make infrastructure-related decisions or departments that deal with city-wide transportation, energy, and environmental sustainability concerns. Automobile manufacturers can be identified as leading companies in the EV industry. This social group is responsible for not only engineering vehicles but also researching and designing energy saving solutions. Examples include giants like Tesla, Toyota, Volkswagen, and General Motors (GM). EV owners are those who use electric vehicles on a regular basis, requiring easy and consistent access to charging stations and clean energy sources. Non-EV owners, in contrast, stick to traditional cars, public transportation, or walking/cycling. This social group would still be impacted by city infrastructure modifications, either directly or indirectly.

Given these groups, I will use actor-network theory (ANT) as the leading STS framework of my research. This theory posits that all human and non-human entities form networks of influence, equally shaping one another through complex relationships to create reality. It was selected because of its ability to map the intricate network modeling my relevant social groups. More specifically, it will allow me to clearly understand how these groups control and depend on one another. I will rely on Sergio Sismondo's "An Introduction to Science and Technology Studies" to guide my use of the framework (Sismondo, 2009). This piece provides an in-depth review of the STS framework, discussing its core characteristics along with various criticisms.

Conclusion

My research is composed of two unrelated projects, both connected to the field of electrical and computer engineering. The technical project is targeted at designing an environmental monitoring device capable of measuring temperature, humidity, air quality, and UV index. Its purpose is to improve the overall health, comfort, and safety of individuals in a variety of indoor and outdoor spaces. Through my STS research project, I intend to answer how cities across the world can best prepare their infrastructure for the incoming surge of electric vehicles. I plan to do this by answering several sub-questions pertaining to charging infrastructure, power grid resilience, and government responsibility in the field of EVs. My research methodology consists of using a variety of academic and non-academic sources, including but not limited to research publications, simulation models, empirical datasets, policy reviews, case studies, and editorials. I will use actor-network theory as my driving STS framework as I examine the intricate relationships between relevant social groups. From a broader perspective, I hope that my research and findings will not only serve as a guide for how to seamlessly integrate EVs into society but also highlight the silent yet significant influence of infrastructure on the world.

Key Texts

1. "Smart City Planning - Developing an Urban Charging Infrastructure for Electric Vehicles"

This paper analyzes the city of Amsterdam to determine the areas where electricity and charging points are used most frequently. Using this data, researchers can develop a model that can predict high utilization areas and help urban planners decide where to place these charge points. This is important to my research because one of my analysis goals was to determine how EV infrastructure can be integrated into future urban planning projects. This paper is also interesting because it considers a city in Europe, which typically possesses different infrastructural characteristics compared to its American counterparts.

2. “Evaluation Of Charging Infrastructure Requirements and Operating Costs for Plug-In Electric Vehicles”

This article examines the various parameters involved in EV charging to determine which factors to consider when trying to minimize costs (the research is specific to California). The primary finding is that charging time is the most critical factor in reducing infrastructure costs, whereas increasing the number of charging stations has only marginal benefits. The paper then goes on to estimate the amount of EV charging resources needed at various locations (i.e. home, work, commercial, etc.) depending on charging strategy (less charging time, greater station counts, or greater output power and average charging time). This is relevant to my project since determining charging station spatial distributions is the core infrastructure decision cities must make. Additionally, cost is something that I must consider for nearly every modification.

3. “Inequitable Access to EV Charging Infrastructure”

This piece underscores the inequitable distribution of charging stations across New York City, noting that “the distribution of EV charging stations is heavily skewed against low–income, Black–identifying, and disinvested neighborhoods.” Its goal is to examine the socio-demographic factors that influence the placement of EV infrastructure. This is a valuable research article as it will allow me to better identify how cities can modify infrastructure while considering the current situation of low-income neighborhoods and not amplifying inequalities.

4. “The Effect of Policy Incentives on Electric Vehicle Adoption”

This piece analyzes the effectiveness of various policy incentives on EV adoption. It also provides insight into how likely different groups of people are to adopt EVs, and what factors dictate that likelihood. The researchers find that policy incentives have a positive effect on adoption. Still, these incentives don’t necessarily have to be financial, as things like free parking or access to bus lanes can be equally impactful. This article is relevant to my research as government incentives could potentially minimize the class and gender divide permeating EV adoption rates and lower total infrastructure investment costs.

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