**Motivation:**

In recent years, shared-use vehicle systems have gained a lot of popularity all over the world. These systems usually consist of a fleet of vehicles that are used by different individuals throughout the day. Shared-use vehicle systems have the potential to become an important link toward building smart and sustainable cities. These systems are attractive because they can potentially reduce the cost of commuting for an average person: people do not necessarily need to buy or lease a vehicle if their usage is limited. The focus of this thesis is to discuss a framework for developing a self-sustaining system capable of managing consumer requirements. Through an E-Vehicle Share System, a consumer can rent a vehicle at any location in the city if there is a working vehicle available at that location, return a vehicle to any location in the city after the consumer is done with its use, and report any defects the user may encounter during vehicle usage. Further, to realize the system in its full complexity, it is also capable of producing an operator interface that will allow the operator to track the location of all vehicles in the city, charge a vehicle when its battery has been depleted, repair vehicles that have been reported as defective by the user, and move vehicles around the city as and when required. To enable the manager to access all the consumer information through intuitive visualizations, a Power BI dashboard has been developed. This thesis will provide an overview of the existing software surveyed to implement the system, discuss suitable approaches to tackle this problem, and explain the design approaches implemented as well as the motivation behind choosing a particular design idea. We will also be discussing the technologies used to realize this system along with the testing procedures implemented.

Aims:

Chapter Structure:

This chapter summarized the motivation and aims behind the development of LegFree. The remaining chapters will go into broader detail and describe the working of the application and how the aims were successfully met. The structure of the remaining chapters is given below:

* **Chapter 2:** Background research of different products in the market and user response to the solutions presented in comparison to pre-existing ways of commute.
* **Chapter 3:** This chapter will focus on describing the MoSCoW prioritization technique and outline the functional and non-functional requirements for all three users (Consumer, Operator, and Manager).
* **Chapter 4:** In this chapter, we will describe the system architecture by going into the details of the deliverable and non-deliverable components of the project. This chapter will also cover the initial project planning stage by describing the ER diagram, activity diagram, paper prototypes, and wireframes.
* **Chapter 5:** The implementation chapter will focus heavily on demonstrating the product, going through different software engineering practices that were implemented, tools and technologies used, and key features and implementation details of the product.
* **Chapter 6:** The penultimate chapter will provide an evaluation of the system by going through different forms of testing methods and evaluating the product from the perspective of both the pilot user and the final user.
* **Chapter 7:** The final chapter will summarise the report, discussing any future work that can potentially make the product better while also providing an overall reflection of the project.

**2. Background Survey**

**Literature**

Widely considered as emerging modes of sustainable transport, mobility on demand (MoD) systems utilize shared vehicles (bikes, scooters, cars), parking spaces, and advanced information technology, allowing users to move from point to point on demand while cities to gain back urban land (Shaheen and Cohen, 2016). With a global fleet of 18 M bikes in more than 2000 cities in 2020 (DeMaio, 2020) and an industry doubling biannually (Worldwide – bike sharing market size), bike sharing systems (BSS) are currently one of the most rapidly growing sectors of urban mobility.

1. **Economics of Vehicle Sharing**

Vehicle sharing systems also have the potential to generate a vast amount of economic benefit to the city in which they are deployed: an empirical analysis (**figure 1)** in Shanghai estimated that the annual saved travel time, cost, and economic benefits from these systems was 17.665 billion min, 6.463 billion CNY (£768 million), and 15.410 billion CNY-eq (£1.8 billion eq), respectively.[[1]](#footnote-1) Despite the advantages these systems offer towards building a sustainable economy, they have a massive challenge of initially onboarding fleets of vehicles at a substantial investment. These systems typically begin generating profit years after they are first released to consumers.

To generate a viable business, market demand needs to be accurately predicted. It is also important to note that after these systems have been deployed, accurate prediction of peak hours helps estimate how many vehicles should be available at a station at any given time. Although vehicle sharing systems potentially offer a viable alternative for enhancing urban mobility, they suffer from the effects of fluctuating demand that leads to severe system inefficiencies. These inefficiencies are embedded into the fabric of bike sharing because one way trips are allowed and the operator has little control over the behaviour of the user. This impedes potential users to pick up or drop off their bikes at a desired station which may lead to user dissatisfaction and eventually may result in the decline of the user base.[[2]](#footnote-2)

Further, the system developed needs to offer a competitive advantage to the consumer by introducing lower prices so as to not let competition gain a higher market share. To thrive in this competitive market, it is vital for bike sharing companies and app developers to understand their competitors, the services they offer, as well as the incentives they provide to their users. These systems can be implemented in three different ways: station-based, dock less, and hybrid. **Table 1** (Table 3 performance summary of three types of systems) summarizes a comparison between three different cities for the different ways of implementing bike sharing systems. Kou et al. conclude that hybrid systems when compared to station-based systems offer a potential benefit of $734 per day in an urban city like Chicago.[[3]](#footnote-3)

(We’ll get to this part later)

1. **Carbon Emission Impact Due to Vehicle Sharing**

It has been estimated that global warming caused due to carbon dioxide emissions will raise the overall temperature of the planet by around 2°C if the current emission trends continue. This will lead a lot of increasingly unstable weather patterns and rise in sea levels. To alleviate the impending challenge we face, bike share systems promise to reduce the emissions by the transport sector significantly if major cities shift to this alternative.

In a case study of Just Eat Cycles in Edinburgh, D’Almeida et al conclude that the environmental impact from a single such bike sharing system can amount to 200 tonnes of reduced emissions. [[4]](#footnote-4) If these systems were to be incorporated into every major city across the world, it would on average amount to 102.4 kilo tonnes of reduced CO2 emissions. These savings don’t take into consideration the impact these systems would have on user behaviour and traffic patterns. Accurate metrics taking these factors into account will produce an even bigger estimate of the potential benefits of implementing these systems.

In another study by Zhang et al, a big data based analysis reveals that bike sharing in Shanghai saved 8,358 tonnes of petrol and decreased CO2 and NOx emissions by 25,240 and 64 tonnes respectively.[[5]](#footnote-5) The benefits observed are directly correlated to the population density of a region. **Figure (Fig. 4. Carbon emissions from the transport sector in Shanghai from 2000 to 2015.)** depicts the carbon emissions from the transport sector in Shanghai from 2000 to 2015. Although the estimates were made using the data from one bike sharing company, they give an idea for how these systems in general have an impact on the emission dynamics of a city.

(Add later if you want to)

1. **User Perspective on Vehicle Sharing Systems**

After World War-II, increased incomes and lower production costs resulted in deep penetration of personal cars in middle class households of developed countries. Wu et al conclude that household vehicle ownership behaviour is governed not only by economic considerations but also by psychological and sociological factors.[[6]](#footnote-6) In previous studies, Koppelman et al explored interrelationships among perceptions, feelings, preferences, and choice using a factor analysis method. They determined that attitude variables other than perceptions of mode performance influence a travellers’ choice for travel modes.[[7]](#footnote-7)

However, the attitude shift is evident in light of different surveys conducted in different cities around the world. In a survey conducted by Shaheen et al in the United States, it was found that members who participate in vehicle sharing systems usually have slightly higher incomes, are younger, and tend to be more educated than the general population in the demographic region.[[8]](#footnote-8) However, this strongly depends on the sample of demographic data being used as is evident in **Table 2 (Table 3 Distribution of Respondent and City Demographics)**

A research report on the adoption of e-scooters published by Populus[[9]](#footnote-9) shows that 70% of the citizens of major cities in the United States expressed a positive attitude towards micro mobility solutions. People generally consider these to be a great alternative to owning a personal vehicle. These studies have demonstrated that people in general are interested in pursuing unusual modes of mobility in favour of moving towards a more sustainable future.

As the response to such systems is positive in general, it is important for governments to be onboard for integrating them into wider city development projects. Cities that develop sustainable mobility solutions will not only have a more interconnected transportation system, but will also be subject to higher economic benefit.

1. **Traffic Congestion Alleviation**

Cities which tend to have higher population densities are more prone to traffic congestion. Reducing the overall number of vehicles on the road is therefore, the most viable solution to alleviating traffic congestion. Some of the reasons which lead to traffic congestion are: improper planning of city development, improper lane management, accidents, and illegal parking. Traffic contributes to air pollution and leads to increased frustration levels among individuals.[[10]](#footnote-10)

By simulating a large-scale mobility on demand system for the city of Prague, Fiedlar et al conclude that these systems can dramatically reduce the number of vehicles needed to satisfy existing transportation demand.[[11]](#footnote-11) Further, for Capital Bike Share based in Washington DC, Hamilton and Wichman point out that the existence of bike share station in a block reduces traffic congestion and the average treatment effect contributes to a 4% reduction.[[12]](#footnote-12) In the study, an obvious increase in ridership during peak hours is also evident from **figure** (Fig. 3. Total count of bikeshare trips made (departures and arrivals) throughout the sample by time of day)

Incentivizing users to also participate in MoD logistics makes the system even more efficient. This helps in managing the amount of bikes in the system to minimize the expected operating cost. Jin et al conclude that the use of dynamic pickup and return rewards can provide very substantial reductions in the operating cost, especially in operating environments with a high traffic intensity of bike returns outside the central location and relative to bike pickups in the system. [[13]](#footnote-13)

1. Gao et al., “Quantifying Economic Benefits from Free-Floating Bike-Sharing Systems.” [↑](#footnote-ref-1)
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4. D’Almeida, Rye, and Pomponi, “Emissions Assessment of Bike Sharing Schemes.” [↑](#footnote-ref-4)
5. Zhang and Mi, “Environmental Benefits of Bike Sharing.” [↑](#footnote-ref-5)
6. Wu, Yamamoto, and Kitamura, “Vehicle Ownership Model That Incorporates the Causal Structure Underlying Attitudes Toward Vehicle Ownership.” [↑](#footnote-ref-6)
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11. Fiedler, Čáp, and Čertický, “Impact of Mobility-on-Demand on Traffic Congestion.” [↑](#footnote-ref-11)
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13. Jin et al., “Dynamic Incentive Schemes for Managing Dockless Bike-Sharing Systems.” [↑](#footnote-ref-13)