Summary

Nowadays, the increase in traffic congestions, land consumption, and pollution emission due to private car ownership makes the rise of shared mobility possible. One of the most spread implementations of shared mobility is Free Floating Car Sharing (FFCS). It is a car rental model where the users can pick and release the car everywhere within an operative area. The customers can reserve (and return) the vehicle using a web-based application. With just a simple tap, the users can unlock and lock the smart vehicle. Usually, the provider bills the users only for the time spend driving, with time-minute based fares. All the other costs, like petrol, insurance, and maintenance, are in charge of the provider.

This service's flexibility fills the urban mobility gap between public transport's relative cheapness and the comfort and capillarity of private car ownership. Indeed, FFCS allows people to travel and commute faster than the standard public bus but avoiding all the fixed and variable costs related to private car ownership.

Given the recent electric cars market increase and all the benefits those vehicles carry, replacing FFCS fleet with electric-powered cars may still improve urban centers' quality of life. The setup and management of an electric FFCS require ingenuity to minimize the users' discomfort due to car plugging procedures.

In my thesis, I present a methodology to address, in different cases of studies, all the challenges related to the conversion of combustion engine cars to electric vehicles in FFCS. In particular, my research's main driver is to propose a methodology to build a profitable and technically sustainable system setup, able to guarantee a flexible and appealing mobility service to an increasing customer audience.

In the first part of my thesis, I describe the software I developed to scrape from the web real combustion engine FFCS, from two providers: car2go and Enjoy. The car2go data collection lasted from December 2016 to January 2018, collecting more than 27 million users' bookings spread in 23 cities. The Enjoy data collection phase started in May 2017 and lasted until June 2019, recording about 6 million bookings in 6 cities.

Then, I characterize both datasets in Turin, one of the cities in which both FFCS providers work. I detect the outliers, filter them out from the dataset, and extract geo-temporal users' travel patterns.

After that, I compare the car2go customer's pattern with the one-way and two-way car-sharing system. The results show how users prefer more flexible services like FFCS

or one-way car sharing.

Once the data are consolidated, I develop: A methodology to place a charging station in a city by looking at users' patterns. System policies to manage the fleet when the vehicle state of charge may not guarantee a trip. Via an event-based trace-driven simulator able to replicate the recorded trips in an electrified scenario evaluating each configuration's feasibility.

Via accurate simulation in Berlin, Milan, Turin, and Vancouver, I study different electric FFCS setup. By placing the charging station in the most frequented areas, by offering an incentive to the users to plug the car when the battery state of charge is below a safety threshold, and balancing the spread of poles, it is possible to obtain a sustainable system covering with charging station only the 8-10 % of zones.

To reduce the number of charging stations to have a sustainable electric FFCS, I compare several optimization algorithms. The results show how a Genetic Algorithm can find a better solution to shrink the minimum amount of resources to sustain the same mobility demand.

After that, I move my attention to the users' rentals' demand predictability. The main goal is to understand how different open-data sources could impact the recorded FFCS users' rental. Initially, I compare several time-series forecasts to predict the users' demand in the short and medium-term. Random Forest regression produces better accuracy and results in terms of interpretability. Then I correlate the socio-economics features characterizing each city neighborhood to FFCS demand, and again, the Random Forest regression outperforms other algorithms.

Finally, I question the system scalability figuring out several scenarios having increasing demand. I use a model to synthesize users' demand by looking only at the geospatial users' rentals. By varying the electric FFCS setup and simulating the new scenario, I point out how a linear increase in the demand intensity requires a fleet sublinear increase. Finally, I project those considerations in euros, proofing how electric FFCS has room for economic growth.