Simulating the impact of shared, autonomous vehicles on urban mobility in Milan - A case study for data-driven decision-making

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Extended Abstract

Recent technological advances in vehicle automation and connectivity have furthered the development of a wide range of innovative mobility concepts such as autonomous driving, on-demand services and electric mobility. In addition, the realm of big-data and artificial intelligence has opened up the opportunities within data analytics. In combination with the ever-growing urbanization (1), awareness of sustainability, and shared economy, these advancements are reshaping the way people move in and around cities and are enabling data-driven decision-making for city planners and policy makers.

Our study on urban mobility in Milan aims at investigating the interplay of these concepts to efficiently reduce vehicle counts in urban environments, thereby reducing congestion levels and creating new public spaces to promote the quality of live in urban cities. Together with the traffic agency AMAT in Milan, we looked at the existing traffic conditions of the city and analyzed the potential of robo-taxis on the aforementioned factors. Currently, the city of Milan, which has one of the highest rates of car-ownership in Europe with 50.5 cars per 100 inhabitants compared to London (31), Berlin (29) or Paris (25), is struggling with severe traffic congestions. Everyday, 850.000 commuters enter the city during the morning rush hour, and even though Milan has an established public transport system, the capacity of road and parking infrastructure does not withstand the extensive motorized individual traffic. In the past, the city has implemented strict vehicle limitations and bans for the city center in the form of the Ecopass and Area C. In the future, digital solutions are to be implemented in the context of an extensive Sustainable Urban Mobility Plan (SUMP) (1). In the context of the SUMP vision, we introduced the concept of robo-taxis as an autonomous and shared mobility service and analyzed its potential using microscopic traffic simulations using the open source software Simulation of Urban Mobility (SUMO, (2))as the simulation environment. Our approach consisted of three main steps: Derive current traffic routes, run traffic simulation for the current state and enhance the simulation with the robo-taxi approach, and derive key takeaways and quick-win opportunities.

Deriving OD-matrix to simulate current traffic

In order to derive individual vehicle or person routes, we first established an origin-destination matrix (OD matrix) for the region of interest in Milan. The OD matrix was calculated from publically available mobile phone usage data made available as part of the Telecom Italia Big Data Challenge 2014 (3). The data covered the metropolitan area of Milan for two months and contained aggregated activity of calls, SMS and internet usage for ten-minute intervals. We segmented the data according to traffic assignment zones and derived density maps for different timestamps during the day (e.g. 5 am, 10 am, and so on). Combining this data with the underlying road network of Milan, which we were able to derive from OpenStreetMaps, allowed us to visualize density shifts throughout the day. We then applied a stochastic approach to derive individual routes for the traffic simulation, satisfying the observed global density shifts. The overall routes where calibrated in SUMO at various points by taking traffic count data, provided by AMAT, into account and using Google Maps Distance Matrix API data on trip duration.

Simulation framework for robo-taxis in SUMO

To establish an efficient simulation environment, we configured a customized toolbox to dynamically run and analyze simulations. SUMO provided a basic vehicle interaction model and real-time simulation interface. For the purpose of this study, custom functionalities for ride sharing and advanced data processing were developed and implemented via Powershell and Python. We used the former to develop a toolbox that allows fast access to various functionality within the SUMO environment, as well as integrating above-mentioned map and route data. The robo-taxi functionality is implemented using the Traffic Control Interface (TraCI) for SUMO. Through TraCI, each vehicle, person, and network element can be distinctly accessed and manipulated at every simulation step. The implementation of the robo-taxi algorithm is based on a thoroughly designed stat-chart framework describing the different status and status transitions of persons and vehicles. A stable marriage algorithm is applied for the matching process, assigning persons with mobility demand to available robo-taxis at each simulation step. In such a case, the algorithm adapts the status of the person (e.g. from 'Unassigned' to 'Assigned') and re-routes the robo-taxi accordingly. Simulations are run with different ratios of classic motorized individual traffic and robo-taxis to analyze the effect on congestion and emissions, all the while recognizing the effect on waiting times of the persons. For the simulation analysis, our setup of the simulation framework also allowed to track output parameters such as travel time, speed, traffic flow, traffic density, waiting time of passengers, and emissions. Based on these parameters, the critical transition rate from private cars to robo-taxis to reach a free-flow state was calculated.

Key takeaways, quick-win opportunities, and outlook

To conclude, our simulations show that shared robo-taxis can be a solution to traffic congestion in Milan. We found that a transition rate of about 50% is required to achieve a significant reduction of traffic congestion levels in peak hours as indicated by mean travel times and vehicle flux. Assuming peak-shaving, e.g. through smart pricing strategies and other incentives, of about 10%, the threshold transition rate drops to 30%. Based on these findings, we see that theoretically introducing a robo-taxi fleet of 9500 vehicles, centered around mid-size 6 seaters, can solve traffic congestion and emission problems in Milan.

Robo-taxis will be a part of future urban mobility and have a positive impact on urban quality of life. Even more, the concept of robo-taxis already affects city planners and policy makers of today. Accordingly, we highlighted "quick wins" and their short-term implementation for optimal utilization of vast infrastructural possibilities and a smooth transition. Overall, the success of robo-taxis greatly depends on the public acceptance, the economic cost-benefit ratio as well as the technical feasibility. Some of our suggestions are: setting up trial areas for human-driven "robo"-taxis to test the service as well as user acceptance; develop pricing strategies to motivate citizens to use shared mobility services and to reduce rush-hour peaks; think about opportunities to reshape the city landscape to increase quality of life (e.g. charging infrastructure, green areas, and more), and to test first available autonomous vehicle concepts.

In the future, further effects of the robo-taxi approach have to be considered, such as intermodal transition rates, intelligent tariffing/pricing models or applying system-wide routing optimization. We also see potential enhancements in the form of prediction models for mobility demand using state-of-the-art machine learning models or intelligent be-in/be-out ticketing solutions based on location data and other technologies. Leveraging know-how in traffic modelling, platform ecosystems, and artificial intelligence enables to integrate innovative technologies and data-driven approaches to generate an added-value e.g. for planning, operations, and governance.

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Keywords: Autonomous driving, robo-taxis, modelling urban mobility, traffic simulation

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