Exploring the limits of shared autonomous micro-mobility

May 27 2022

Clip from the demo video of the MIT Autonomous Bicycle Project. Credit: Jimmy Day

What will be the impact of shared autonomous micro-mobility systems? Will autonomy make micro-mobility systems even more efficient and attractive? Researchers at the MIT City Science group explore this and many other questions by using an agent-based simulation tool built ad-hoc to analyze the fleet behavior of shared autonomous micro-mobility

systems. In a case study, the authors assess the potential impacts of autonomous shared bicycles.

The two papers that they recently published related to this research are available in *Communications in Transportation Research*.

Cities urgently need innovative solutions to global challenges such as urban population growth, inequality, and climate change. Mobility is one of the fields that requires a radical transformation. By redesigning urban mobility systems, we can move towards a future in which cities are more livable, equitable, sustainable, and resilient.

In the last decade, bike-sharing systems quickly proliferated in cities worldwide. More recently, other micro-mobility systems such as e-scooters have become a mainstream inner-city transportation mode. However, despite their popularity, shared micro-mobility modes still face several challenges. First, due to the uneven user travel patterns, system operators need to rebalance the vehicles throughout the city in vans or trucks, which has a very high economic and ecological impact. Second, due to the low costs of the vehicles and the market's competitiveness in dockless systems, operators flood cities with vehicles exceeding the capacity of the urban infrastructure and generating many urban and environmental problems.

The MIT City Science team proposes the introduction of autonomy as a solution to mitigate some of these challenges, making shared micro-mobility systems more efficient and convenient. In the first place, autonomous vehicles would rebalance themselves, solving the rebalancing problem for system operators and, by being more efficient, could mitigate the current vehicle oversupply challenges.

At the same time, autonomy could allow shared micro-mobility systems to work as a mobility-on-demand service. This means bringing the

convenience of systems like Uber or Lyft into sustainable modes of transportation. In an autonomous shared micro-mobility system, trips would occur as follows: A user would request a ride through a mobile app, and an autonomous vehicle would drive to the user's location. While waiting, the users can enjoy their time for other purposes instead of being on the street trying to find an available vehicle. Once the vehicle arrives, the user would ride to their desired destination. Then, upon arrival at the destination, the vehicle would drive autonomously to pick up another user, to a charging station, or towards wherever the demand is predicted to occur. This improved user experience could incentivize more people to use micro-mobility systems as their preferred trip mode and allow more people to travel around their cities in environmentally friendly ways.

Due to the novelty of introducing autonomous driving technology into shared micro-mobility and the inherent complexity of these systems, there is a need to quantify the potential impact of autonomy on fleet performance and user experience. Therefore, in a first paper, the authors present an agent-based simulation tool developed ad-hoc to assess the performance of shared autonomous micro-mobility. The tool allows different stakeholders to gain insights into the performance of this emerging form of urban mobility in order to make informed decisions related to their design, development, or implementation, among others.

The presented tool provides the flexibility, adaptability, resolution, and speed required for this research. For example, users can quickly transfer the model from one city to another. The tool also presents parameters at different levels that allow for customization of the characteristics of the autonomous micro-mobility system being modeled. Therefore, users can model various shared micro-mobility systems such as bikes, scooters, or three-wheelers. In addition, it allows comparing the performance of an autonomous system with current station-based and dockless schemes, providing a quantitative analysis of the potential benefits and drawbacks.

Moreover, since the model scales linearly with the number of trips and vehicles, researchers can study different modeling hypotheses and scenarios in very reasonable run times. Lastly, and perhaps most importantly, thanks to its flexibility, adaptability, and speed, the tool can be easily adjusted to re-evaluate results as these systems evolve and more data becomes available.

Autonomous shared bicycles as a case-study

As an example application of the presented simulation tool, in a second paper, the authors present a study that provides an in-depth understanding of the fleet behavior of autonomous bicycle-sharing systems. The vehicle they take as a reference for this modeling work is the MIT Autonomous Bicycle Project. This bicycle dynamically transforms into a tricycle for lateral stability during autonomous driving. Hence the system offers two configurations: When a user is riding it, the system is in bicycle mode. The two rear wheels act as a single wheel, and the riding experience remains unchanged from riding a regular bike. In contrast, when the bicycle is driving autonomously, the bike is in tricycle configuration. In this case, the wheels separate and provide the necessary lateral stability for the autonomous drive.

In this second paper, the authors model the performance of a fleet of shared autonomous bicycles like the MIT Autonomous Bicycle in different realistic operating conditions taking Boston in the U.S. as a scenario. The performance of the autonomous system is compared with current station-based and dockless schemes, quantifying the extent to which an autonomous system could outperform current bicycle-sharing systems.

This analysis provides a very detailed overview of each system's characteristics, including average trip and waiting times, percentage of served trips, and the utilization of the bicycles, among many others.

These results answer some of the most central questions in shared autonomous systems, such as the relationship between the wait times and the fleet size, or the relationship between an autonomous bicycle's speed on system efficiency and user experience. Furthermore, the article also assesses the impact of different parameters on system performance by running batch simulations with a range of values for each parameter. In addition, this simulation investigates the effects of various operational strategies, including no rebalancing, ideal rebalancing, and a demand-prediction-based rebalancing model.

The obtained results show that with a fleet size 3.5 times smaller than a station-based system and 8 times smaller than a dockless system, an autonomous system can improve overall performance and user experience, even with no rebalancing. These findings indicate that the remarkable efficiency of an autonomous bicycle-sharing system could compensate for the additional cost of autonomous bicycles.

This case study demonstrates how insights generated through the simulation tool that the authors propose can be valuable for many stakeholders. Firstly, it can provide fleet operators with guidelines for designing, implementing, and operating an autonomous bicycle-sharing system. In addition, it provides insights that can assist engineers in defining the vehicle's design requirements. Lastly, it can help city planners and governments understand the potential urban and environmental impacts to determine the regulations and incentive mechanisms related to these new mobility modes. Ideally, by having the necessary evaluation tools, stakeholders will be able to align the different urban, social, environmental, engineering, and economic issues to everyone's best interests.

More information: Naroa Coretti Sanchez et al, On the simulation of shared autonomous micro-mobility, *Communications in Transportation Research* (2022). DOI: 10.1016/j.commtr.2022.100065