Shared Autonomous Vehicles Implementation for a Disrupted Public Transport Network

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Abstract

The paper proposes the management of bus disruption (e.g. fleet failure) and maintain a resilient transportation system through a synergy between shared autonomous vehicles and the existing public transport system based on the organizational structure and demand characteristics. The methodology is applied to the region of Rennes (France) and its surroundings.

Keywords: disruption management, shared autonomous vehicles, public transport, simulation

1 Introduction

According to the mobility observatory set up by the UTP (Union des Transports Public) in 2021, 64 % of French people use regularly public transport, and the demand is increasing. This success can be explained by the increase in the quality of the transport offer: punctuality, frequency, cleanliness, and by the growth of the offer in quantitative terms. Today, more than 73 % of French people have access to a public transport network. However, the bus is the most developed mode because it is suitable for all urban densities. It represents today 86 % of the urban public transport vehicle fleet.

Given this unprecedented increase, disruptions of public transport can significantly affect a big number of travelers. Road works, road closures and accidents are just some of the causes of delays and disruptions in transport systems. The limited frequency of the public transport service can deter travelers from using the service [Kwa18], and a poor connectivity of the system requires travelers to transfer multiple times to reach their destinations, which results in a longer travel time leading to longer journey time [Boa17]. Hence the importance of finding a way to maintain a resilient transportation system, which means able to preserve a good quality of service even when faced to disruptions [Mah19].

A resilient system can minimize the disaster impacts with its inherent ability to maintain the reasonable performance of system components and enables the rapid restoration of the system. Maintaining a resilient transportation system may be very costly, needs an important back up fleet and an agile management.

Emerging autonomous vehicle technology is often touted by its proponents as a solution to many of these challenges. Shared Autonomous Vehicles can offer on-demand mobility service inexpensive and without emissions [Kru16; She18]. Previous studies also suggested that the integration of Shared Autonomous vehicles can accompany and increase the performance of existing public transport services [She18].

Our study aims to reduce the effects of bus lines disruptions using shared autonomous vehicles as a supplement to the existent public transport service. It allows to identify the potential of the integrated system to enhance service quality, decrease the cost of this kind of disruption for the travelers and operators as well.

2 Methodology

The study is conducted by implementing a multimodal network with mode choice, and to couple shared autonomous vehicles with public transport to increase the performance of the transport system in the case of a disruption.

The methodology consists of simulating the traffic of Rennes and surroundings in different circumstances, i.e. normal traffic and disrupted traffic, then integrating autonomous vehicles as an alternative in the disrupted traffic scenario. Therefore, the problem is divided into two cases:

1. Simulate public transport demand for the given perturbation event.
2. Simulate the integration of the shared autonomous vehicles as a supplement to the existent public transport service.

Simulations are made essentially on the transport network between a suburb of Rennes, Chantepie, and the city center of Rennes. There are 3 bus lines directly connecting Chantepie to Rennes, namely lines C1, 13 and 34. The disruption events are mainly created on these lines.

This work is accomplished using the multi-agent simulation model MATSim, where a traffic flow simulation is done with many other functionalities like demand-modeling, re-planning strategies, and output analysis.

3 Results and Discussion

By simulating the two cases, the analysis of different output attributes (travel time, waiting time, walking time, emissions, and travel cost) will lead to the best choice to be made by the passengers in the given disruption, and this will show the impact of integrating the shared autonomous vehicles in this region.

The first simulation informs us about the amount of damage caused by the disruption. For example, the increase of the travel time of the passengers going from Rosa Parks in Chantepie to Republique in the downtown of Rennes, considered as one of the Origin-Destination demands. Before disruption, these passengers can make this trip on bus line C1, for a distance of 7106 meters. The trip travel time is usually between 27 and 39 minutes. While after the disruption, the travel time is increased by almost an hour compared to the normal case, because of the transfers to other bus lines made by passengers to reach their destination.

The second simulation estimate how much the integration of shared autonomous vehicles can be useful to this disruption case. Figure 1 shows the decrease of the travel time of some passengers that are still using the public transport system after disruption, by the integration of shared autonomous vehicles. The decrease is about 15 minutes, compared to the travel time in disruption case. The integration of the shared autonomous vehicles helps in increasing the performance of the public transport system after disruption.

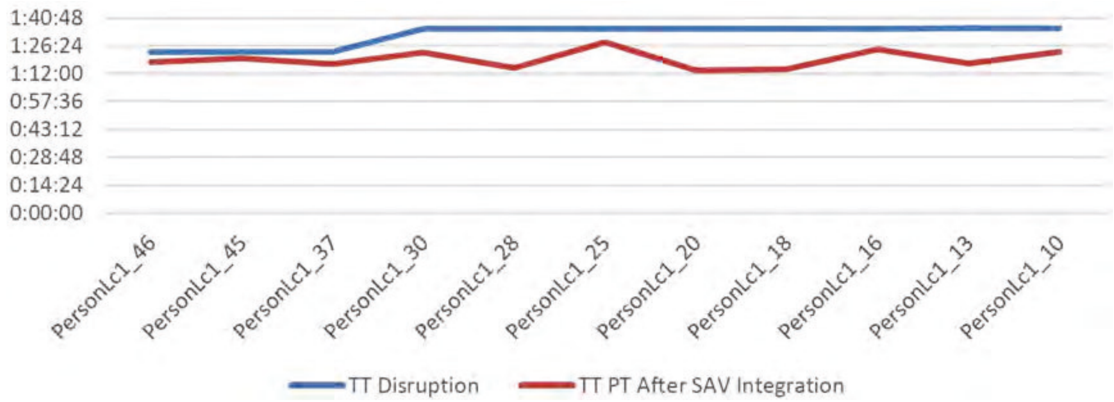

Figure 1: Comparison of the travel time for few passengers using PT after disruption (blue) and using PT after the integration of SAV (red).

4 Conclusions

Shared autonomous vehicles integration into a public transport system with specific demand can potentially encourage a higher public transport system usage. This integration can help to cover the dysconnectivity in the existing public transport network and increase the accessibility of the service. The autonomous service can also be cheaper and more environment friendly. When the cost of the shared autonomous vehicles becomes low, passengers are more likely to choose the sequence of modes “walk - shared autonomous vehicle - walk” for the whole trip instead of coupling it with public transport.

However, these results depend on the topology of the studied region, the limitations of public transport service in this region, and the type of the disruption event.

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