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Utilizing Virtual Singapore Platform to Quantify Benefits of Autonomous Vehicles

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Abstract:

This study discusses on methods of measuring Autonomous Vehicles' benefits in the urban city of Singapore. The study has exploited AV modelling and simulation techniques in Virtual environment. The team has made use of AV simulation software in conjunction with traffic simulation and architecture design software. The AV simulation software provides the capability of deploying different sensors such as virtual LIDAR with physics based rendering, vision sensors, Inertial Measurement Unit (IMU) etc. These sensor measurements help the vehicles to interpret surrounding environment used for localization, perception, path planning etc. For a realistic environment, we have integrated the simulation software with a real-time traffic simulator. This traffic simulator is able to populate vehicles based on real-traffic conditions. The real traffic data is collected with help of our research collaborator, Land Transport Authority (LTA), Singapore. The integration of traffic data and simulator together helps to test and analyse different use cases to quantify the benefits like area saving, transit time etc. and express the challenges involved in adapting Singapore to an AV environment. This paper presents a perspective of utilizing Virtual Singapore platform for testing and validating AV deployment in Singapore road network through a combined interface of different software.

Introduction:

Autonomous Vehicles (AVs) are a highly anticipated innovation in the intelligent transportation industry and we are seeing a significant surge in its growth. Scientists, engineers and policy-makers around the world are working together in reducing the gap where AV becomes a reality. The transportation and infrastructure industries are collaborating and defining their investment priorities in order to adapt to the upcoming advancements of AVs. We are also seeing AVs as an upcoming option for improving first mile and last mile connectivity. The micro transportation model such as shared e-scooters and e-bikes has received mixed reviews in terms of safety and comfort from both users and non-users of the service. As all these involved industries race to make AVs a reality, we will witness major infrastructure changes in urban cities adapting to driverless future. Hence, it is crucial that the stakeholders get a realistic view of changes to enable informed decisions.

The Virtual Singapore project is a NRF (National Research Foundation) initiative and a dynamic 3D model of Singapore bringing together all the urban elements in a virtual platform. It is a collaborative data platform that enables different sectors to test and develop tools for planning and decision making using virtual simulation techniques. This also opens up an opportunity to simulate scenarios, estimate the changes required for making AV a reality and quantifying the benefits of the technology.

Urban mobility and associated congestion is a recognized and yet an increasingly complex challenge. The technological advances in virtual simulation, IoT, AI and machine learning linked with city transportation has created myriad opportunities for cities to overcome these challenges [1]. On the other hand, there are significant advances in the multidisciplinary field of Intelligent Transportation Systems (ITS) combined with information technology [2]. Most existing work on ITS focusses on assisting human drivers to avoid collision in intersections [3], [4]. Hence, there is significant studies on safety and manoeuvring of AV. Considering the existing studies, we realized that there is a gap on the changes in infrastructure and its impact on the urban environment that is inclusive of AVs. Hence, this study proposes infrastructure changes with respect to Singapore district Area of Interest (AOI).

Virtual Environment for Autonomous Vehicles

Virtual environment offers several advantages for the study of future mobility technologies. It allows simulating different potential landscapes as well as synthetically generated and/or real traffic through collected data. There are much varied applications for AV virtual environment simulator. Wang et al 2005 has used the virtual environment to model the road surfaces to allow easier road distance calculation [5]. Donikian 1997 has developed a model of the virtual urban environment to study the realistic behaviour of car drivers and pedestrians and their interaction with each other [6]. In case of Singapore and Nanyang Technological University (NTU), in particular, NTU and LTA have led to the development of CETRAN (Centre of Excellence for Testing & Research of AVs – NTU (CETRAN), meant for test requirements and standards to deploy AVs [7].

This study has explored the virtual environment of Ang Mo Kio district in Singapore for validation and verification of AV as a technology. The project has used the virtual environment of VTD and Vissim software along with Autoware ROS for understanding the dynamics of autonomous vehicles with surrounding landscape and real time traffic. This is accomplished by deploying virtual LIDAR along with real traffic data in the environment.

In addition to the analysis of AV as a technology, we have looked into how AV pick-up and drop-off points can be designed in order to streamline their movement during peak/non-peak hours. For first/last mile mobility, it is expected that most of the connectivity would be required to/from Mass Railway Transport (MRT / train) stations. However, demand for the vehicle may surge during peak hours or in the event of a breakdown. Hence, we have concentrated our study at the train stations in Singapore that see large number of commuters on daily basis on any typical day.

Proposed Infrastructure changes

Figure 1 shows the current simulation environment developed for the area of Ang Mo Kio. The image shows a combination of data received from the funding agency and data developed by the research team for the study.

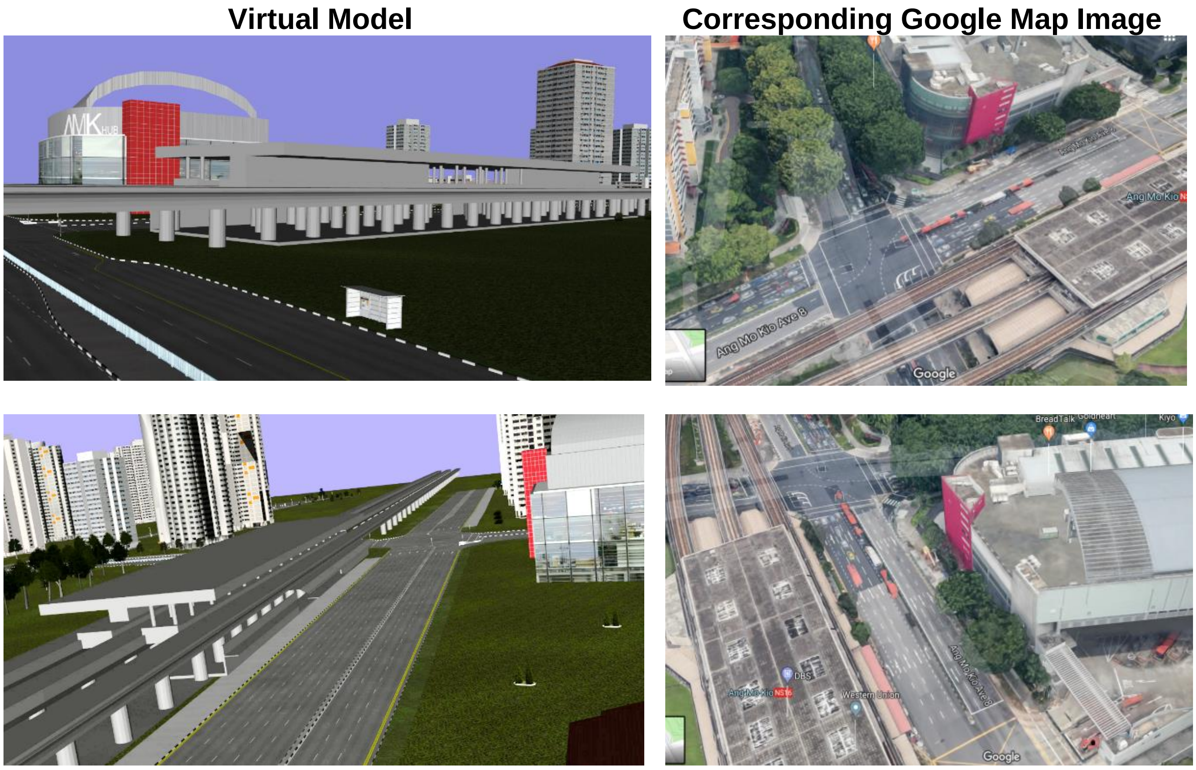

Figure 1: Virtual Environment of Singapore vs Google Map images of the same area

The image shows the existing / baseline scenario of AOI. To meet the demands of peak hours and occasional public transport breakdown and to ensure that accumulation of AVs does not create any bottlenecks, the passenger loading/unloading areas is redesigned, to achieve maximum throughput.

Option 1

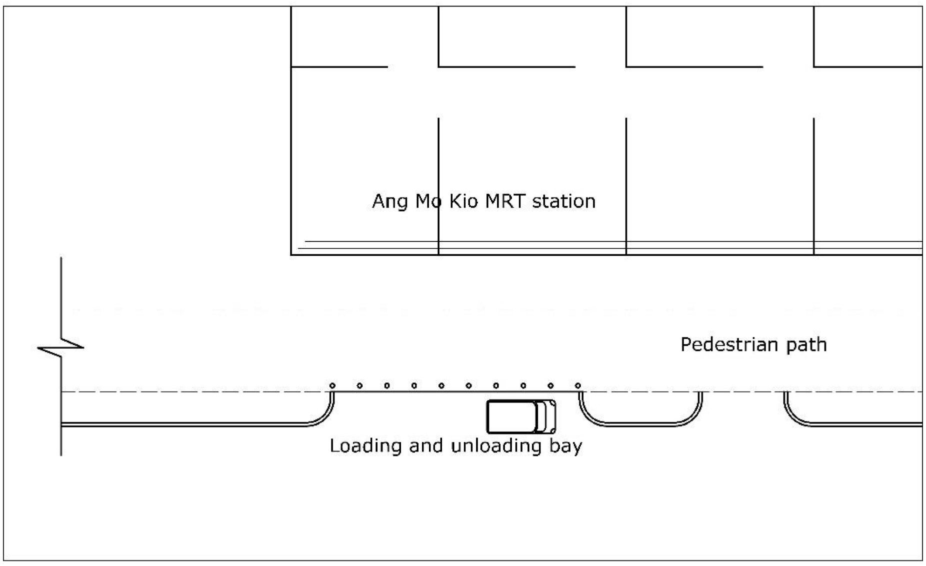

Figure 2: Baseline Scenario for loading and unloading bay at AOI

Figure 2 shows an existing loading/unloading bay along the MRT station. The first case is assuming this loading and unloading bay as a stopover for AVs along with its original function. This proposed option does not require any changes in the existing infrastructure but rather a modification in existing road and traffic policies that allows this sharing.

Option 2

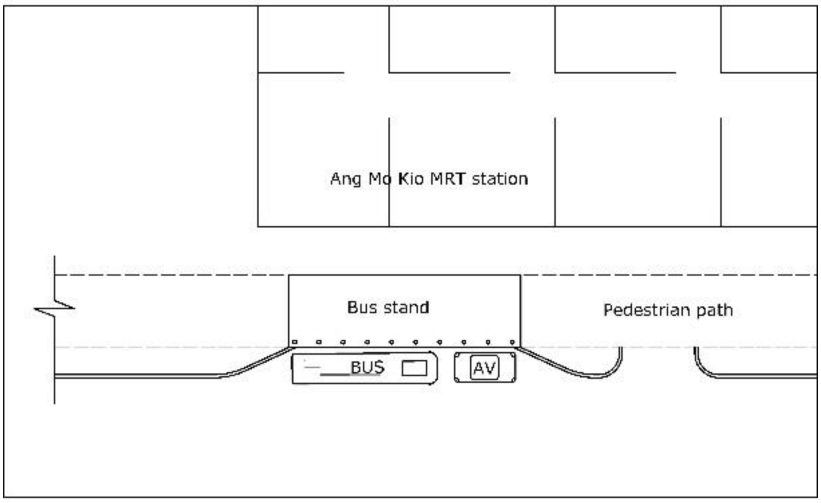

Figure 3: Existing infrastructure with propose change AV and Bus position

Ang Mo Kio MRT has a bus interchange in the basement floor so there is no bus stand next to the MRT station on the ground level. However, usually a bus stand is located along a MRT station. To replicate the similar condition, in option 2, we are assuming loading and unloading bay as an existing bus stand. The AVs are can potentially share this space with buses as pick up and drop off area. The bay length is approximate 20m which is enough for one average 4 seater car sized AV and one bus to park simultaneously. We will be simulating various conditions as depicted in Figure 3 considering time required for pick up and drop off at the designated stop. The figure shows arrival of AV at the stop when a bus is already at the stand.

Option 3

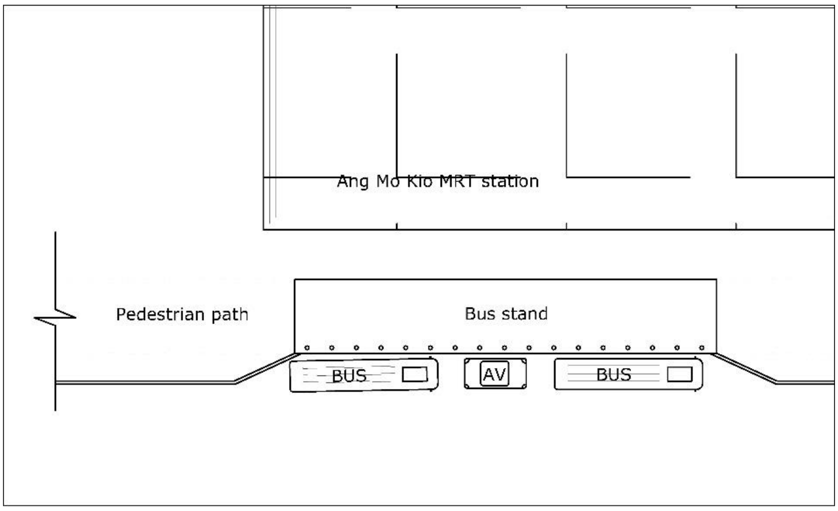

Figure 4: Proposed Infrastructure change with modified bus stand length

Option 3 is updated version of option 2, where the length of the bay is increased. In this scenario we are assuming to have a longer bus stand bay. The length is assumed to 35m which can cater to two busses along with one AV simultaneously or multiple AVs with one bus at any given time. The scenarios in option 3 can be numerous. Couple of scenarios are depicted in Figure 5 and 6. The conditions will have another variable of time of stop required by AVs and busses for pick up and drop off of passengers.

Option 4

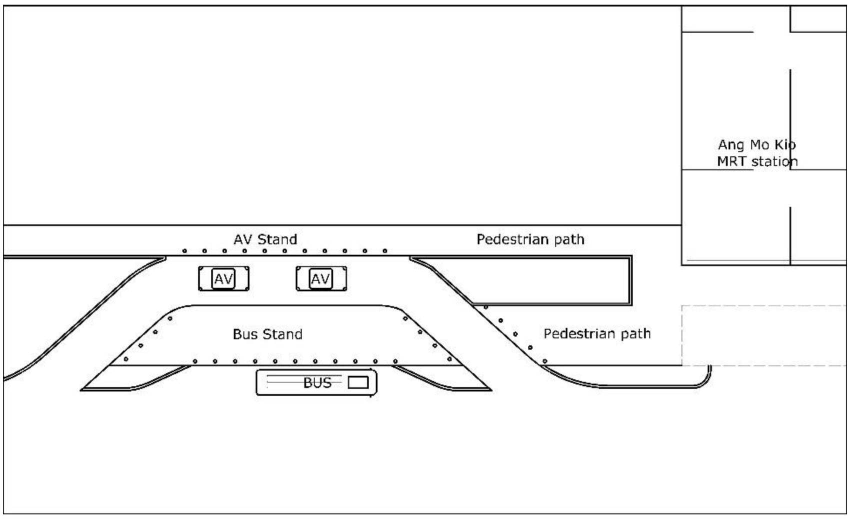

Figure 5: Proposed infrastructure change with dedicated AV lane

Option 4 has a separate dedicated lane for AVs which is aligned in parallel with the bus stand as shown in Figure 5. This option can be viable only around the MRT station with large spaces available.

Implementation of proposed changes

The most significant impact with these changes is its effect on traffic. This section proposes a methodology of calculating and quantifying the saving on time. The team is using a combination of VTD software powered through ROS Autoware for navigation, localization and perception and Vissim for traffic simulation.

Figure 1 is a baseline scenario in VTD software whereas figure 2 to figure 5 are preliminary designs digitized using AutoCAD. The following steps will be taken for calculating the impact of changes in traffic.

1) Implementation of road layout changes in simulator. This implies the transfer of proposed parking bay and drop-off AutoCAD designs to VTD and Vissim as changes in their road layout. These changes in the road layout will influence the movement of all traffic objects which can then be evaluated quantitatively.
2) Importing realistic Singapore infrastructure through Virtual Singapore. This entails converting the format of 3D models of Virtual Singapore into one which is compatible with the simulator so that the sensors modelled in the simulator can detect this virtual environment in a realistic manner. This step is crucial as it ensures that the AV is being tested in the actual Singapore environment and it will help to identify the gaps in the existing infrastructure for being conducive to the deployment of AVs in future.
3) Scenario generation in VTD – The traffic objects in VTD will be programmed to depict scenarios such as those shown in Figure 2 to figure 5 and the AV will have to manoeuvre in each test scenario of this first / last mile connectivity. Since, different layouts will impact the AV’s movement for the test scenarios differently, this will

eventually impact the overall travel time of the AV which is our main quantitative metric for evaluation of AV as service. The simulator will also enable us to evaluate other aspects of AV such as safety and comfort of the passengers and other traffic objects that it interacts with by looking at parameters such as headway, braking, acceleration and steering profile of the AV. A robust comparison of all these test scenarios under various combinations of infrastructure and road layouts will help in an educated proposal of necessary changes in the Singapore transportation network for accommodating AVs in an efficient manner.

Conclusion

The project utilizes various software to develop virtual environment of a part of Ang Mo Kio district in Singapore. This environment is capable of simulating AVs. We have utilized the environment to propose infrastructure changes and have discussed the methodology to calculate the impact of infrastructure changes with respect to real traffic data of the region and provide quantified results of different scenarios.

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