City of Monash

Glen Waverley 2036

Preparing Glen Waverley Station for Autonomous Vehicles

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Context

1 Introduction

1.1 Background

As the most important technological advancement of the transportation system in the current century, the widespread adoption of autonomous vehicles (AVs) technology heralds the prospect of automated transportation, and the development and operation of AVs will fundamentally change the market of mobility and disruptively impact urban planning (Fagnant & Kockelman, 2015). At present, autonomous technology is considered to have various potential economic and social benefits, which can achieve the sustainability goals of the transport network and urban system.

AVs can enhance the safety of driving while also reducing the incidence of accidents by declining the reflection time and buffer distance (Park et al., 2017). Autonomous vehicles can provide non-drivers with an independent mobility option by filling the gaps of the first and last mile, such as for the disabled, the elderly as well as for children. It is also notable that AVs may reduce traffic congestion and related costs by improving road capacity. With the development of AV technology, the performance of urban lands could be improved because AVs are able to drive and park themselves at a certain distance from users, which can reduce the demand for parking lots in dense commercial, residential and workplace environments (Vantsevich, Howell, Vysotski & Kharytonchyk, 2003).

With these remarkable advantages, AV technology will become a dominant personal travel choice and affect all travel modes, including public transportation, which will significantly change the city's transportation system and urban built environment (Moore & Lu, 2011). However, relevant research is currently lacking, this is especially concerning how AV technology affects the essential nodes of high-capacity public transport, such as airports and train stations, and how AV technology shapes the urban space around them.

This report will first review the development trend of AV technology, as well as AV vehicle design and application. Based on the literature review, the problem will be described and research questions will then be proposed. Secondly, this report will use the Glen Waverley station as a case study, and indicate its current situation and challenges. The third part will apply the scenario planning method as a means to design three scenarios, which involves different configuration and penetration of AVs. In addition, the implication of different scenarios will be summarized in the fourth section. Finally, transport strategies and actions will be proposed.

1.2 Literature Review

1.2.1 Trend in Autonomous Vehicle Technology

Autonomous vehicles are defined as vehicles that can safely drive themselves without human intervention by using a combination of sensors, visual calculations, lidars, surveillance devices, and high-end processing capabilities (Enzweiler, 2015). When automakers introduced semi-automated technology into personal cars, it gives rise to autonomous vehicles. The national highway traffic safety administration (NHTSA) alongside the Society of Automotive Engineers (SAE) proposed two automation standards of AVs (SAE International, 2014 & NHTSA, 2013). This research will discuss the SAE standards (Figure 1), including the following five AV technology levels. Level 1 and Level 2 AVs are already sold on the market.

Autonomous vehicles currently have a long list of ever-growing entities involved in the AV technology. Most commercial AV technology research is currently at level 1 or 2 (Nikitas, Kougias, Alyavina & Njoya Tchouamou, 2017). These partially automated systems are often combined into Advanced Driver Assistance Systems (ADAS) and have become a standard on new vehicles, including automatic braking, smart cruise control and automatic parking systems. The Telsa Model S produced by the Tesla company is at the level 3 stage, and it is still necessary for the driver to be prepared to intervene when the ADAS system is activated. This is not to mention that the Google car is at level 4, and the driver will not monitor the vehicle unless there are special circumstances. Since the launch of the project in 2009, Google's self-driving team has travelled more than 1.2 million miles in autonomous mode (Gibbs, 2017).

No driving automation (level 0)

- You drive it.
- The driver always has entire control of the main vehicle actions — braking, steering, throttle and power— and monitors the surroundings.

Driver assistance (level 1)

- Hands on the wheel.
- At this level, it is necessary for the driver to fully participate in the overall vehicle control. The vehicles should have advanced driver assistance functions, such as adaptive cruise control and parking assistance. Most modern cars comply with Level 1 of the SAE Standard.

Partial assistance (Level 2)

- Hands off the wheel, eyes on the road.
- The driver is responsible for monitoring the road and is always ready to control the vehicle. This level involves the automation of at least two major control functions, such as adaptive cruise control and lane centering.

Conditional assistance (Level 3)

- Hands off the wheel, eyes off the road.
- At this level of automation, the car monitors the surroundings and handles all braking, steering and throttle systems in a specific environment. The vehicle can recognize its limitations and require the driver to resume dynamic driving tasks within an ample time margin.

High automation (level 4)

- Hands off, eyes off, mind off-sometimes.
- The vehicle system is able to extensively perform all critical driving functions and monitor road conditions throughout the journey. It can drive in the right environment throughout the entire day, and if it isn't able to cope, it can seek help from people.

Full automation (level 5)

- Mind off.
- In many cases, level 5 vehicles do not require human operation. The driver simply sets the destination and starts the car, then the car handles all the other transactions.

Figure 1 Levels of driving automation according to the Society of Automotive Engineers

Source: Adapted from SEA J3016 (SAE, 2014)

Figure 2 forecasts the evolution of the forecasted AV technology. 25% of traffic will be autonomous vehicles in 2030. By 2064, driverless cars will be used worldwide.

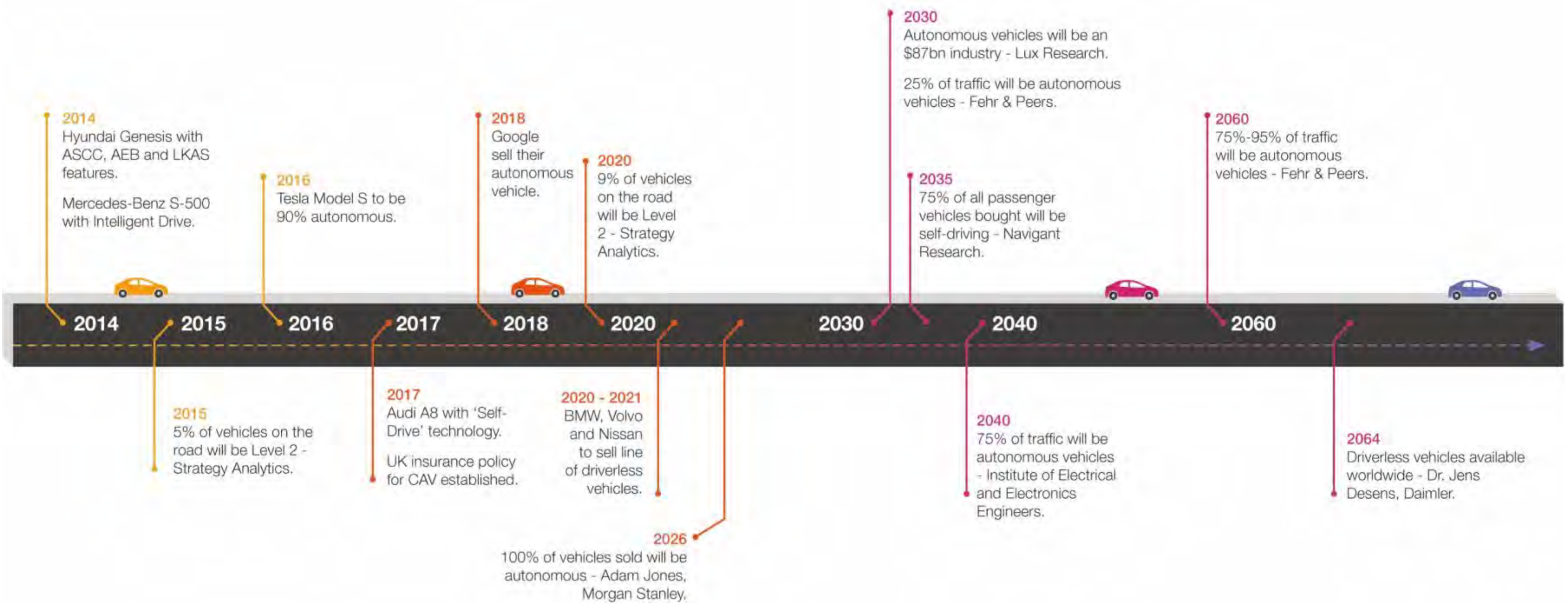


Figure 2 Forecast the evolution of the forecasted AV technology

Source: Presentation of Mark Rowland (2018)

1.2.2 Shared Autonomous Vehicles

There are two aspects of shared autonomous vehicles: shared car ownership or unrelated people sharing a ride on a specific trip (Shen, Zhang & Zhao, 2018). The ride-share mode is considered more convenient than in comparison with the car-share since it has been universally implemented through smartphone applications, such as urban pool and Waze Carpool. It is notable that ride-share cars can be managed and operated by public or private companies, achieving a different hierarchy of membership. Considering the agent-based model, Zhang et al. (2015) applied the dynamic co-multiplication method to simulate the performance of ride shared autonomous vehicles. Their research reflects that SAV can reduce travel costs and mileage, declining the risk of trip delays. If AVs are allowed for general extensive travel while the cost of the driver is cancelled, the demand for ride share will be further increased. In addition, the digital platform that utilizes these smartphone applications to convene taxis or ride-share cars is an essential innovation in the transportation services, which represents an important step towards demand-responsive travel (Alam & Habib, 2018). In this article, shared AV defaults to ride-share AVs and AV bus.

1.3 Problem Statement

As a high-capacity public transport, trains play an essential role in the daily lives of residents. In Melbourne, more than 20,000 people travel by train. From the 2011 to 2016 period, the proportion of mode shares of Melbourne LGA trains increased from 51.2% to 56.4% (Stone & Woodcock, 2018). As an important transportation hub, the railway station not only undertakes the mission of resident travel and transfer, but also stimulates economic growth and increases opportunities for community activities (Baek, 2014).

In the suburbs, train travels are almost always part of the travel chain, and the accessibility of the train station is a critical component of customer experience (Charles, 2013). The public chooses different modes of transport to access the train for long distance travel, such as driving, bus, walking and cycling, which shape the spatial space near the train station. For instance, car-oriented access methods may cause traffic congestion during the morning peaks and highlight the demand of parking space. With the increase of population, residents' demand for accessible and reliable train stations will continue to improve. The application of AV technology will inevitably change the personal travel mode as well as the development of public transport. However, the research of the ways in which AVs affect the urban transport hub is limited. Various uncertainties still exist, such as the influence of configuration and penetration rate of AVs.

The purpose of this paper is to measure the potential development model of train station under the influence of a traffic system with AVs, and provide specifically integrated transport strategy planning. The study presented in this report investigates the impact of different configurations of AVs based on scenarios planning on train station space.

1.4 Scope and Research Question

The scope of this article covers the Glen Waverley station. The research questions discussed in this report are as follows:

Which configuration of AV technology can make the best use of public space of stations?

What will different scenarios mean at the Glen Waverley station?

How have AVs reshaped the space around the station?

2. Current Situation of Glen Waverley Station

2.1 Regional and local context

Glen Waverley station is located in Glen Waverley activity Center (GWAC), Monash city, about 19 km from Melbourne CBD (Figure 3). GWAC is considered to be an essential node of Monash City, playing an important role in commercial and civic activities. With convenient transport network, GWAC can quickly reach the neighboring cities through the Springwell Road. Moreover, GWAC is only 10 kilometers away from the Monash employment and innovation clusters, which allows GWAC to share the radiance of these of innovative industries (Urbis, 2014). In addition, the GWAC is attractive and vibrant due to its diverse infrastructures, such as retail shopping centers, supermarkets, and movie theatres, which provide recreational facilities and employment opportunities for the residents in the region.

Figure 3. Location of Glen Waverley Suburb
Source: Land Checker (2018)

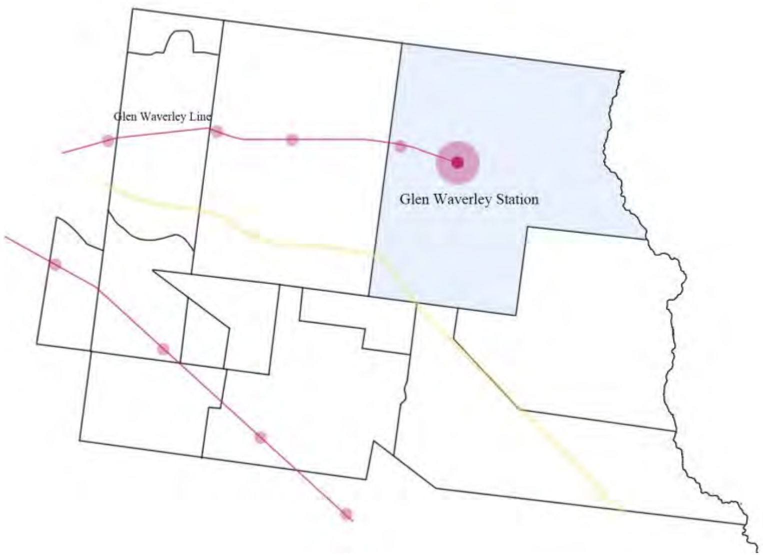


Figure 4. Location of Glen Waverley Station
Source: Land Checker (2018)

Glen Waverley station is an essential public transport hub in this area (Figure 4). As the terminal of the Glen Waverley line, Glen Waverley station provides residents with convenient methods to access to the urban and inner suburbs. As one of Melbourne's busiest train station, more than 6,000 people enter the station every weekday (PTV data, 2012). Combined with the bus interchange, the Glen Waverley station allows commuters to achieve the seamless link between the train and bus.

2.2 Related Planning and Strategy

In *Plan Melbourne 2017-2050* (2017), GWAC is listed as a Major Activity Center, and active traffic is encouraged (Figure 5). However, although this is a 30-year long-term plan, this plan does not consider the impact of autonomous technology on traffic.

From the level of the city, *Monash Planning Scheme* (2018) provides detailed strategies for GWAC's transportation network. This plan supports integrated public transport as an attractive and logical choice for GWAC. Walking and cycling are prioritized to achieve a convenient and safe network, and parking spaces should be accessible and easy to find to minimize interference with pedestrians and cyclists. In response to the *Monash Planning Scheme*, *Monash Council Plan 2017-2021*(2017) indicates that the bus interchange should be upgraded and the priority of pedestrians will be strengthened in GWAC. Besides, the council mentioned that Glen Waverly central parking space should be rebuilt.

A lot of detailed planning was also proposed to guide the development of transportation. *Monash Walking and Cycling Strategy* (2015) show that residents of all ages and abilities, including those in wheelchairs, parents with children, or children on scooters, will be considered in the construction of walking and cycling-friendly Monash City. *Glen Waverley Activity Centre Structure* (2016) proposes a phased approach to reconstruct the road network near Glen Waverly station to improve the traffic performance. However, further implementation plans have not been proposed.

The *Glen Waverley Activity Centre—Sustainable Transport Plan* (2014) responds to the above-mentioned planning strategies and indicates the current situation of Glen Waverley station, as well as further proposing specific objectives for supporting multiple travel methods to reduce the traffic congestion caused by excessive reliance on private motor vehicles.

Considering the vision of the above plan form a long-term perspective, the development of Glen Waverley station should consider the influence of AV technology and incorporate it to encourage a variety of sustainable transport modes and give priority to bicycles and walks.

Figure 5 Strategy and Policy Framework Analyzed in This Report
Source: author

2.3 Current Transport Situation

2.3.1 Access modes of Glen Waverley Station

According to the PTV data (2012), more than 6,000 people entered the Glen Waverley station every weekday. As shown in Table 1, this station is private car-oriented, and over 46% of people choose to travel by cars. More than 1800 people choose to walk, accounting for 30.3%. Although the bus interchange is close to the train station, fewer people travelled by bus compared with private cars, accounting for 21.7%. Besides, only 31 people choose cycling to access the station.

GW 2012 access mode	Thru-put/weekday (No. of People)	Mode share
Car	2886	46.60%
Bus	1344	21.70%
Walked	1875	30.30%
Cycled	31	0.50%
Other	57	0.90%
Total	6193	100%

Table 1 Access mode in 2012
Source: PTV data (2012)

Figure 6 Land use within 400m Radius
Source: Adopted from Land checker

2.3.2 Land Use within 400m Radius

Located in the GWAC, the land near the train station is mainly for commercial use (Figure 6). Around the activity center, part of the land is designated as a residential growth zone for satisfying the demand of housing.

2.3.3 Active Transport

According to the survey, the accessibility of the roads around the GW station is relatively high, but most pedestrians think that the road experience is poor. Because private cars are the primary access mode of the train station, the spatial layout and road designs around the train station are car-priority. The road infrastructure and landscape facilities are not pedestrian-friendly.

Figure 7 Sidewalk and bicycle network

Figure 8 Current traffic flow and Parking space

The cycling environment around the train station is less than ideal; there is only one bicycle path which provides access to the train station, which is Coleman parade on the south side. However, security risks still exist on this road because of the lack of specific bicycle lanes and effective signage.

2.3.4 Road Network, Parking Space and Kerb Space

Private vehicles mainly access the station through the Railway parade North and Coleman parade from the Kingsway, and the Railway parade North and Coleman Parade are one-way streets with total 125 linear meters of pick up and drop off area (Table 2).

As shown in Figure 8, the train station is surrounded by nine car parks which, together, provide over 40,000 square meters of free parking space. However, the vast majority of parking spaces are time-limited and allow only 332 parking lots for parking throughout the day. The attraction of the parking buildings to the driver is not enough. Although the two parking buildings of Euneva Car Park and Bogong Avenue car park provide 900 parking lots, the occupancy rate of the weekday is less than 60% (Monash City Council, 2014).

2.3.5 Bus

Close to the train station, the bus interchange station acts as a feeder for the station, providing passengers with cross-suburban travel that the train cannot offer (Figure 9). As shown in Table 3, the bus interchange station has a total of 11 bays and 11 bus lines.

Figure 9 Bus Interchange

Private Car	
Number of formal park and ride spaces	332
Area (sqm) of formal park and ride lot	4532sqm
Area (sqm) of timed general parking	41483sqm
Linear metres of dedicated 'kiss and ride' drop off zone	125m
On street parking controls within 400m of station	6245 m
Linear metres unrestricted	0 m
Linear metres timed (less than 8 hours duration)	6245 m
Linear metres permit zone	365 m
Number unrestricted spaces within 400m of station	0 spaces

Table 2 Parking Data
Source: Tang & Yap (2018)

Bus Routes	Destination
623	St Kilda
734	Glen Iris
736	Mitcham
737	Croydon Stn/Monash Uni
742	Chadstone/Eastland
753	Bayswater
754	Rowille
850	Dandenong
902	Chelsea/Airport West
885	Springvale
967	Bayswater
Total Kerb Space	180 Meters

Table 3 Feeder bus Data
Source: Tang & Yap (2018)

2.4 Current Challenges

Serving as an essential hub for residents' daily commuting, the future planning of the Glen Waverley station should consider sustainability. Therefore, the disadvantages of the current transport system should be identified and upgraded.

The increasing utilization of private cars has caused significant challenges for Glen Waverley stations in traffic congestion, lack of parking spaces, and insufficient kerb space. At the morning peak, a large number of private cars flood into the station; the roads are narrow, and traffic flow is intensive, causing terrible traffic congestion. Moreover, only 125 meters of kerb space is set on a one-way street, which not only fails to meet the needs of residents but also may aggravate traffic congestion. In particular, residents often complain that parking spaces are difficult to find, while a significant amount of parking space is provided in this area with low occupancy rate (Monash City Council, 2014). It is worth considering how to improve the utilization and accessibility of the existing parking space.

The bus service should also be improved through the provision of reliable service and comfortable waiting environment. At present, passengers state that the frequency of bus lines should be increased to shorten waiting time. Besides, the bus interchange station provides a weak environment for pedestrians and presents poor connection with the surrounding streets.

For pedestrians, safe sidewalks and intersections around the train station should be improved. Due to the high traffic volume and the deficiency of clear signal guidance, the paths are not pedestrian-friendly in the GWAC, especially the passage from the train station to the Glen Waverley secondary college. Moreover, the basic infrastructure of the street, such as street greening, public furniture, and lighting—is insufficient to achieve attractive walking environment. For cyclists, limited bicycle access and potential safety risks present serious challenges. At present, only the Coleman parade is included in the Monash riding path, and the poor accessibility of path makes it difficult for residents to reach their desired destinations by bicycle easily. Besides, the design of the Coleman parade does not provide specific riding lanes and effective signage, and cyclists must share roads with motor vehicles.

3 Setting the scenarios

3.1 Trend Analysis

Population Forecast

As the terminal of the Glen Waverley train line, the Glen Waverley station serves five suburbs due to its easy access and convenience of a supporting bus and road network. By 2036, the total population growth in the five suburbs is forecast to increase by nearly 125%, which will significantly affect the total number of entries of Glen Waverley station (Forecast ID, 2018).

Suburb population	Population 2018	Population 2036	Change 2018-36
Glen Waverley	42827	46775	9.22%
Wheelers hill	21425	23920	11.65%
Vermont south	12143	13638	12.31%
Wantirna south	22797	25763	13.01%
Scoresby	6058	10797	78.22%
Total	76395	84333	**125%**

Table 4 Population Forecast
Source: Forecast ID (2018)

Employment Growth

The employment rate within GWAC is expected to grow by 10% by 2036. As the hub with the most significant activity in the region, the GWAC has abundant and vibrant commercial facilities, which support the development of employment opportunities. Moreover, proximity to the

Monash National Employment and Innovation Cluster enables GWAC to extend its economic and industrial reach, which can lead to further increase in employment (Urbis, 2014).

Therefore, considering both the impact of population and employment growth, the number of people utilizing the Glen Waverley train station is expected to increase by a total of 135% by 2036.

3.2 Traffic Flow & Road Capacity & Parking Space

3.2.1 Traffic Flow & Road Capacity & Parking Space

As shown in Table 5, the proportion of AM peak traffic reached the maximum of the weekday, accounting for 18.3% per hour (PTV data, 2012). However, based on the survey, 7:30-8:30am is the busiest hour during AM peak. Therefore, in this report, the AM peak hour is defaulted to 7:30-8:29 am, assuming 25% of all day traffic.

Weekday total entries	Pre AM peak (pre 7:00)	AM peak (7-9:29am)	Inter-peak (9:30am-2:59pm)	PM peak (3:00pm-7:00pm)	PM late (after 7:00pm)
6192	1008	2830	1183	958	212
	16.28%	45.70% (18.3% Per hour)	19.11%	15.47%	3.42%

Table 5 Traffic Flow on Weekdays

Source: PTV data (2012)

Road Capacity In terms of Design manual for roads and bridges (1999), the capacity of the road around the train station is calculated in table 6.

Road name	AM peak car Volume	Total number of Lanes	Road type	Road capacity
Kingsway (north end)	2290	4+ lanes	UAP2	3300
Kingsway (middle)	2158	4+ lanes	UAP2	3300
Kingsway (south end)	1369	2 lanes	UAP3	1700
Coleman Parade (east end)	840	2 lanes	UAP 2	1470
Coleman Parade (west end)	1579	2 lanes	UAP2	1470
Railway Parade North	1631	2 lanes	UAP3	1110
O'Sullivan Road	367	2 lanes	UAP 2	1550

Table 6 Road Capacity

Source: adapted from Design manual for roads and bridges (1999)

Types of AVs

In this report, four kinds of AVs will be introduced, including level 0-4 private cars, single occupancy AVs, ride-shared AVs and AV buses (Table 7).

Occupied Time From the investigation conducted at Tullamarine airport, taxis with single passengers occupy less time on kerb space. The entire process is completed within an average of 2 minutes, including payment, carrying baggage and drop off (Virgato et al., 2018). Without the payment and luggage, the occupied time for single AV is also assumed to be 2 minutes, due to consideration of the needs of different groups, weather conditions and potential queuing time. Similarly, the capacity of ride-shared AVs is predicted to have four passengers with an occupied time of 4 minutes. Furthermore, the current bus schedule at peak hours is 15-20 minutes per trip, and each route occupies a single bus bay causing inefficiency. The AV bus will share the bay and the occupied time will be decreased to 10 minutes.

Kerb Space and Turnover Rate According to the observation of the taxi drop-off and pick up areas around the station, 8 linear meters of kerb space allows for fast and safe driving in and out of taxies with a length of 4.7 meters. AV cars will be smarter in driving in and out. Based on this evidence, Table 6 shows the length of the different types of AVs and the required length of kerb space. Also, regarding Lv, Guo & Zhang (2017), kerb space turnover = 60/average occupied time (minutes).

Types of AVs	Length (m)	Avg. Capacity	Kerb space (linear meters)	Avg. Occupied time (minute)
Level 0-4 private car	4.5m	1.2	–	–
Single occupancy AVs	4m	1	7m	2
Ride-shared AVs	5m	4	9m	4
AV bus	12m	30	20m	10

Table 7 Kerb space and Occupied time of different AVs

Parking Space In this report, single occupancy AVs will not need parking space because they can park themselves further away to reduce the negative impact on the station. Temporary parking space will be provided to the ride-shared AVs to decline the empty cars on the street (Table 8). Besides, long-term parking spaces will be provided for Level 0-4 private cars (Table 9).

Types of AVs	Length (m)	Avg. Capacity	Parking space (Sqm)	Avg. Occupied time (minute)
Ride-shared AVs	5	4	15	10

Table 8 Parking Space for Ride-shared AVs

Types of AVs	Length (m)	Avg. Capacity	Parking space (Sqm)	Avg. Occupied time (hour)
Level 0-4 Private Car	4.5	1.2	15	4h

Table 9 Parking Space for Level 0-4 Private Car

3.2 Scenarios

This section will evaluate three scenarios, including scenario 1—single occupancy AVs replacing all private cars and buses; scenario 2—shared AVs replacing all private vehicles and buses; and scenario 3, which includes multiple AVs types. The implication of each scenario will be analyzed.

3.3.1 Scenario 1

In this scenario, all private cars and buses were replaced by single AVs (Table 10).

As shown in Table 9, Single occupant AVs will reach 69.22% in 2036, and the AM peak car volume around the train station will reach 2519 vehicles per hour.

2036 access mode	People Thru-put/weekday (people)	Mode share	People thru-put at peak hour (25% of total)	AM peak car volume (per hour)	Required Kerb space (Linear Meters)	Efficiency (ppl/m/h)
Single occupancy AVs	10,074	69.22%	2,519	2519	588m	4.29
Walked	4,407	30.28%	1,102	–		_
Cycled	73	0.50%	18	–		_
Total	14,554	100.00%	3,639	**2519**	_	_

Table 10 Access mode of Scenario 1

Kerb Space (Table 11)

The turnover rate of each kerb per hour is 60/2=30. The total number of the kerb is 2519/30=84. If the length of each kerb is 7 meters, the total required lengths are 84*7=588 meters.

Types	AM peak car volume	Capacity	Occupied time (minute)	Turnover rate (per hour)	Req. kerb bay number	Length of per kerb bay (linear meters)	Req. kerb Space (Linear Meters)
Single occupancy AVs	2519	1	2	30	84	7	588m

Table 11 Kerb space for Scenario 1

Implications (Figure 10 &11)

1. The total traffic flow at AM peak will exceed road capacity. The traffic flow of the railway parade north is about half of the total traffic volume, accounting for 1260 vehicles, which exceeds the theoretical road capacity of 1110 vehicles (Monash City Council, 2014);
2. The 588-meter pick up and drop off area is required, which means a deficit of 283 meters;
3. Dense traffic flow will increase traffic congestion and lead to unsafe crossroads and bicycle paths;
4. AV technology may not be able to support the high penetration rate of single occupancy AVs by 2036;
5. Not everyone can afford the cost of single occupancy AVs;
6. Singular services are less likely to meet the needs of different types of people;
7. Parking spaces can be significantly reduced, and this space can be utilized for commercial and open space.

Dorp off and pick up area
Potential business
Potential green space
Traffic flow of Single occpancy AVs
Potential enhanced Sidewalks

Figure 10 Traffic Flow of Scenerio 1

Dorp off and pick up area
Potential business
Potential green space
Traffic flow of Single occpancy AVs

Figure 11 Kerb Space of Scenerio 1

3.3.2 Scenario 2

In this scenario, Shared AV and AV buses will replace all private cars and ordinary buses, accounting for 47.52% and 21.7%, respectively (Table 12). The total traffic volume at the AM peak is 458 vehicles.

2036 access mode	People Thru-put / Weekday (people)	Mode share	People thru-put at peak hour (25% of total)	AM peak car volume (per hour)
Shared AVs (4-6) Avg. 4 of people	6,916	47.52%	1,729	432
AV bus (30-60) Avg. 30 of people	3,158	21.70%	790	26
Walked	4,407	30.28%	1,102	–
Cycled	73	0.50%	18	–
Total	14,554	100.00%	3,639	458

Table 12 Access mode of Scenario 2

Kerb Space (Table 13)

For shared AVs, assuming the average carrying capacity is 4 people per car, then 432 vehicles are required. The turnover rate of each kerb is 60/4=15 times, and the total number of the required kerb is 432/15=29. Each kerb has a length of 9 meters; the total length of kerb space is 29*9=261 meters.

For the AV bus, 1729 people will be able to transit during AM peak, assuming an average of 30 people per bus. The total number of buses required is 790/30 = 26 vehicles. The turnover rate for each bay is 60/6 =10; If each bay is 20 linear meters, the total length required is 5*20=100 meters.

Types of AVs	Avg. Capacity	AM peak car Volume	Occupied time (Minute)	Turnover rate (per hour)	Req. kerb bay number	Length of per kerb bay (linear meters)	Req. kerb Space (Linear Meters)	Efficiency (ppl/m/h)
Ride-shared AVs (4-6)	4	432	4	15	29	9	261	6.67
AV bus (30-60)	30	26	10	6	5	20	100	7.90
Total		458					361	

Table 13 Kerb space for Scenario 2

Parking Space (Table 14)

Based on an extreme assumption, if all ride-shared AVs at AM peak require temporary parking and each car takes 10 minutes, the turnover rate per hour per parking lot is 60/10=6 times. The total number of needed parking space is 346/6=58. If each parking lot is 15 square meters, the total required parking space is 15*58=1081 square meters.

Types of Vehicles	AM peak car Volume	Avg. capacity	Avg. occupied time (minute)	Turnover rate (per hour)	Req. parking lot(number)	Req. Parking space (Sqm)
Ride-share AVs (4-6p)	432	4	10	6	72	1081

Table 14 Parking Space for Scenario 2

Implications (Figure 12 &13)

1. The total traffic volume is 458 vehicles per hour, which can effectively reduce traffic congestion. More road space could be released to provide a more safe and comfortable environment for pedestrians and cyclists;
2. A total of 361 meters of kerb space should be provided and the gap is 56 meters;

3. Almost all parking space can be cancelled. Only ride-shared AVs require 1081 square meters of temporary parking space;
4. Six bus bays can be reduced as five bus bays are efficient to meet the demand;
5. Shared AVs and AV buses can meet the needs of different passengers;
6. Not all passengers are willing to accept shared AV;
7. The allocation of kerb space to the railway north will aggravate traffic congestion at crossroads and the bus interchange.

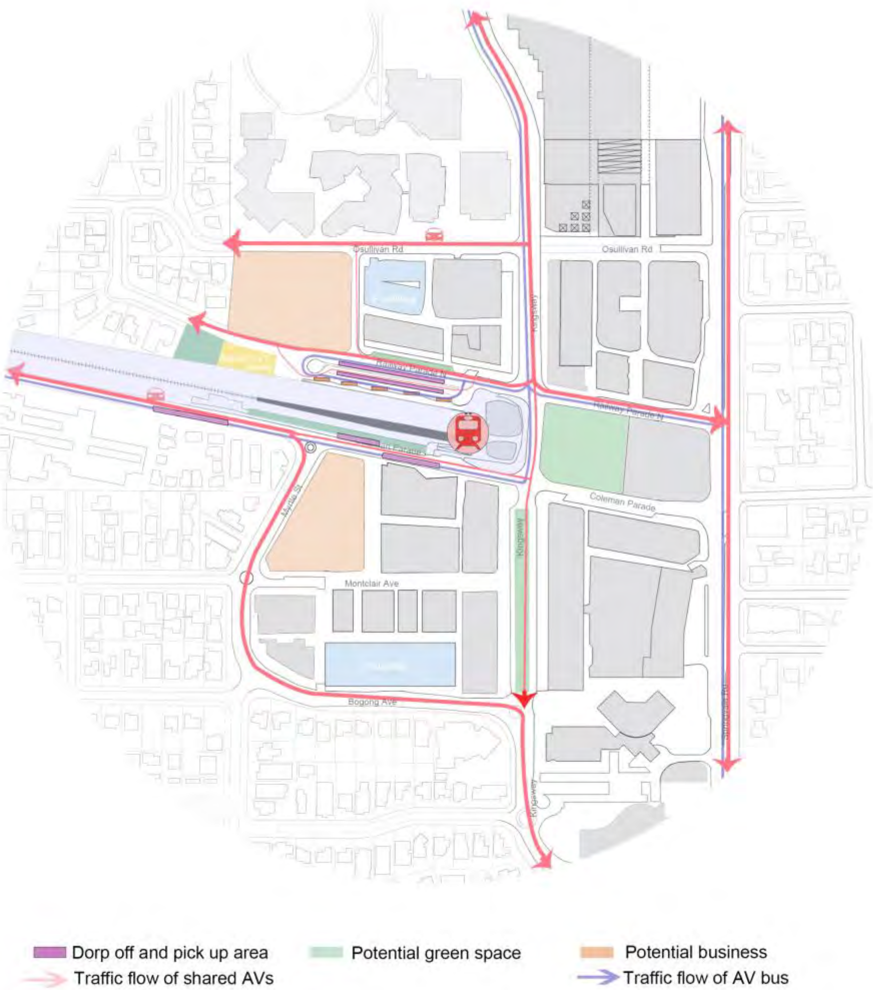


Figure 12 Traffic Flow of Scenario 2

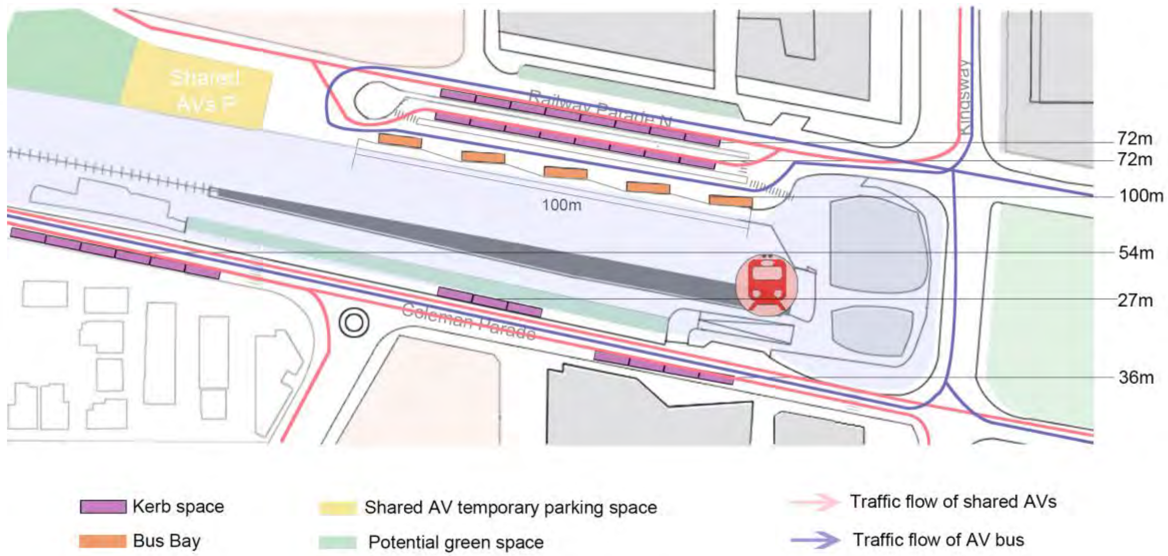


Figure 13 Kerb Space of Scenario 2

3.3.3 Scenario 3

This scenario is based on the conjecture that 2036 is a transition period. Multiple types of AVs coexist in this period, including level 0-4 private cars, level 5 single occupancy cars, ride-shared AVs and AV buses (Table 15).

2036 access mode	People Thru-put/weekday (people)	Mode share	People thru-put at peak hour (25% of total)	AM peak car volume (per hour)
Level 0-4 Private car (Avg. 1.2 of people)	1,455	10.00%	364	303
Level 5 single occupancy AVs	1,455	10.00%	364	364
Ride-shared AVs (4-6p)	2,183	15.00%	546	136
AV Bus (30-60p)	3,639	25.00%	910	20
Walked	5,094	35.00%	1,273	-
Cycled	728	5.00%	182	-
Total	14,554	100.00%	3,639	824

Table 15 Access mode of Scenario 3

Kerb Space (Table 16)

For level 5 single occupancy AVs, the number of entries per hour is 364 vehicles. The carrying capacity of each car is 1 person, and the total number of vehicles required is 363 vehicles. Then turnover rate is 60/2=30, and the total number of kerb bays needed is 363/30=12; with 7 meters for each kerb, the total kerb space required by level 5 single AVs is 7*12=84 meters;

For ride-shared AVs, the number of arrivals is 546 vehicles per hour. Each vehicle can carry 4 people, 137 cars are needed. The total required kerb space is 9*9=81 square meters.

For AV buses, if each bus carries 30 people, 910/30 = 30 buses are needed per hour. Each bay can be converted 6 times per hour, and 5 bays can meet the needs of 21 buses. Assuming each bay is 20 meters in length, the total kerb spaced required is 5*20=100 meters.

Types of AVs	Avg. Capacity	AM peak car Volume	Occupied time (Minute)	Turnover rate (per hour)	Req. kerb space (number)	Length of per kerb bay (meters)	Req. kerb Space (Linear Metres)	efficiency (ppl/m/h)
Level 5 single occupancy AVs	1	364	2	30	12	7	84	4.33
Ride-shared AVs (4-6p)	4	137	4	15	9	9	81	6.74
AV Bus (30-60p)	30	30	10	6	5	20	100	9.10
Total		531					265	

Table 16 Kerb Space for Scenario 3

Parking Space

As shown in Table 17, the total number of people using private cars to enter this station on weekdays was 1455.

According to Lv, Guo & Zhang (2017), **No. of private car parking space = private car volume / average number of passengers/parking turnover rate.** The average carrying capacity of each vehicle is 1.2 people (Vic road, 2012). If the average occupancy time of a private car is 4 hours, then the daily turnover rate is 24/4 = 6 times; total required parking lots: 1455/1.2/6=202. If each parking space is 15 meters, the total space of parking needed is 15*202 = 3031 square meters.

Types of Vehicles	People Thru-put/weekday	Avg. Capacity	Car Volume / weekday	Avg. occupied time (hour)	Turnover rate (per day)	req. parking lot (number)	Req. parking space (Sqm)
Level 0-4 Private car (Avg. 1.2 of people)	1455	1.2	1213	4	6	202	3031

Table 17 Parking Space for Level 0-4 cars

For ride shared-AVs (Table 18), assuming all ride-shared AV require temporary parking space, the peak car volume is 137 vehicles. If the occupancy time of each vehicle is 10 minutes, then the turnover rate per hour is: 60/10 = 6 times. The total number of parking lots is 137/6=23. Assuming each parking lot is 15 square meters, the required parking space is 15*18=273 square meters.

Types of Vehicles	People thru-put at peak hour (25% of total)	Avg. Capacity	AM peak car Volume	Avg. occupied time (minute)	Turnover rate (per hour)	req. parking lot(number)	Req. parking space (Sqm)
Ride-shared AVs (4-6p)	546	4	137	10	6	23	341

Table 18 Parking Space for Ride-share AVs

Implications

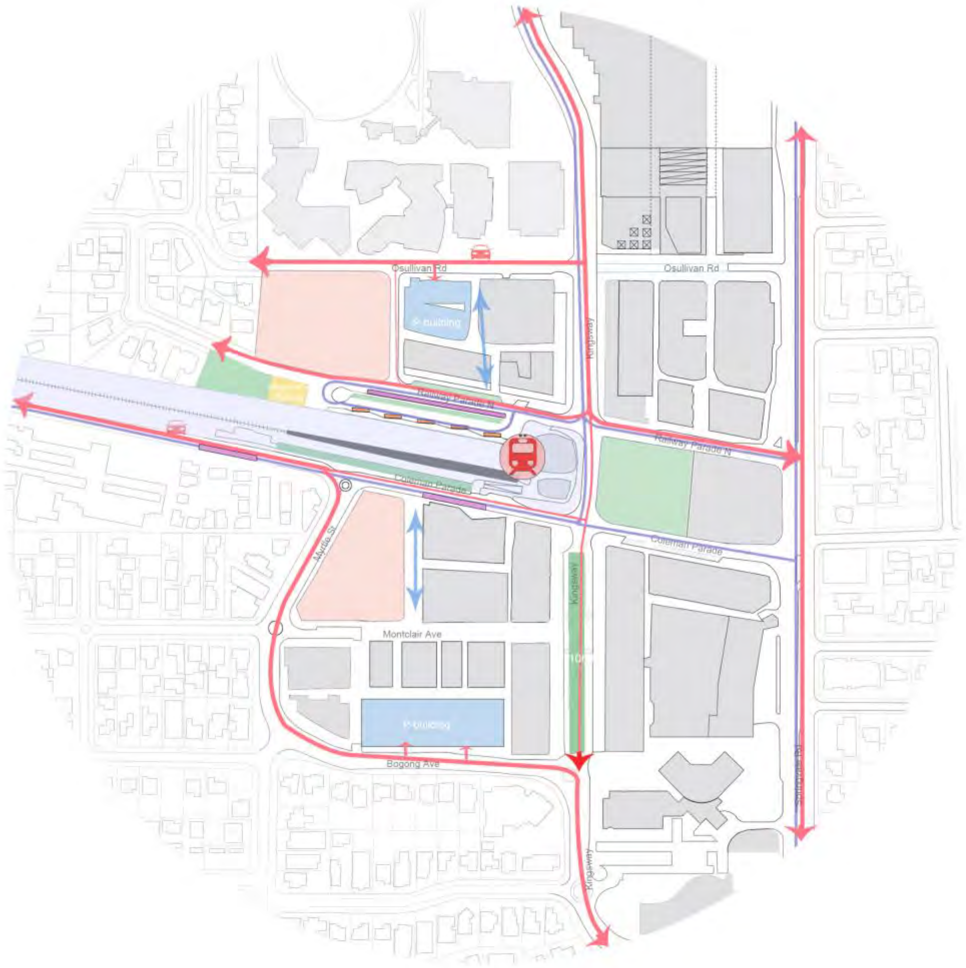
1. In this scenario, the AM peak car volume is 494, which has the potential to relieve traffic congestion;

2. Only 265 meters of kerb space is required, and 40 meters is surplus;

3. A total of 3,372 square meters of parking space should be provided. Level 0-4 private car needs 3031 square meters of long-term parking space, which can be satisfied by the 8,000 square meters of Euneva Car Park and Bogong Avenue car park building. Private vehicles are required to enter the building directly from O'sullivan Road and Bogong Avenue to reduce the traffic volume in Railway Parade North Temporary parking spaces needed by ride-shared AVs could be deployed around the station to meet the high turnover rate;

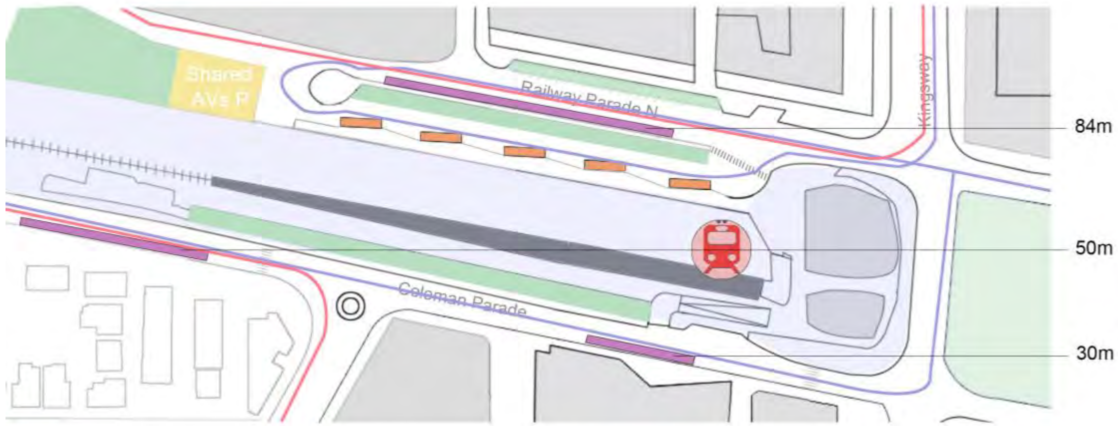
4. The bus interchange station can be combined with the kerb space design of shared AVs, and 6 bus bays can be removed;

5. As a transition period, multiple commuting patterns are analyzed to provide choices for different groups of people.



Dorp off and pick up area | Potential business | Traffic flow of shared AVs & single AVs & level 0-4 private car
Potential green space | Potential enhanced Sidewalks | Traffic flow of AV bus

Figure 14 Traffic Flow of Scenario 3



Kerb space | Shared AV temporary parking space | Traffic flow of single AVs and shared AV
Bus Bay | Potential green space | Traffic flow of AV bus

Figure 15 Kerb Space of Scenario 3

3.3 Results

Based on the above three scenarios, the introduction of AV technology can effectively reduce on-street and on-ground parking space. Compared to private cars, shared AVs can support traditional transportation for first and last mile connections (Zhang & Guhathakurta, 2017). Moreover, a significant amount of valuable space can be released for commercial use and green open space. In addition, through renovating the released road space, AV technology can encourage cycle and walk by providing a safe and accessible road environment.

However, compared to scenario 1 and 2, the traffic configuration of scenario 3 is more reasonable and has a higher space efficiency rate. Based on the level of development trends of AV technology forecast for 2036, various modes of traffic are considered in this scenario. First, according to (Jain & Weiskircher, 2014), 50% of traffic will be AVs. Scenario 3 assumes that half of the private cars are traditional private cars and half are AVs, and the deployment of all AV public transport is feasible. Second, with AV technology, the traffic flow during peak hours in scenario 3 meets the road capacity. Reasonable traffic flow lines reduce interruptions to the mixed lanes and improve the safety of crossroads and roads. Moreover, a variety of modes of access meets the needs of different groups of people, such as the disabled, the elderly and children.

4. Strategies

Based on scenario planning, AV cars can save significantly more space than traditional vehicles, especially parking and road space. Compared to single occupancy AVs, Ride-shared AVs and AV buses have higher space efficiency and are pedestrian-friendly as well as safe on the road, which could be encouraged in the future. This report will propose five strategies to achieve an integrated traffic system of the Glen Waverley station by 2036.

Strategy 1. Optimize road system in the GWAC

Objectives	Actions
1. Improve the performance of road space	• Provide enough drop off/pick up areas to serve the passengers without obstructing free flow in the mixed lane.
	• Develop new street types and cross sections for different types of streets.
	• The design AV's kerb space should do not conflict with other access modes.
2. Improve the amenity of the street	• Support the design of a pedestrian priority to promote GWAC's community and business vitality.
	• limit car volume of Kingsway through time control, and remove on-street parking.
	• provide adequate infrastructure, including green infrastructure and street furniture.

Strategy 2. Improve public transport performance (AV bus and Ride-shared AVs) by providing flexible and reliable services

Objectives	Actions
1. Improve the efficiency of AV bus service	• Integrate bus bay efficiency and reduce waiting time through frequency optimization and train schedules coordination.
	• Increase the comfort of bus bays by providing a green canopy and shelter furniture.
	• Investigate the driving forces and obstacles of residents' choices of AV buses, to provide targeted services for residents.
2. Enhancing the attractiveness and competitiveness of ride-shared AVs	• Enables Ride-shared AVs to be flexibly shuttled to facilitate traffic connections of the first mile and the last mile.
	• offer temporary parking space for shared AVs to satisfy passenger need for different time periods and reduce empty cars.
	• Provide on-demand AV transfer services in the suburbs to improve children, the disabled and elderly mobility.
	• Encourage ride-shared AVs through providing micro-traffic services that could be applied in particular use cases, such as paratransit or late-night service.
	• improve cost competitiveness and provide high accessibility.

Strategy 3. Provide a safe and friendly environment for pedestrians and cyclists

Objectives	Actions
1. Upgrade the walking system to encourage walking	• Establish infrastructure standards to determine gaps in infrastructure within this area.
	• Utilize released road space to optimize the pedestrian experience.
	• Upgrade links between drop off zones and train station entrances.
	• Design a new safe pedestrian path connecting the Glen Waverley secondary college and train stations.
2. Provide safe intersections	• Combining AV technology to design pedestrian-priority intersections, especially at the Railway and North and Coleman parade.
	• Limit vehicle speed in the area.
3. Provide a highly accessible and safe riding network	• Provide a new pedestrian path connecting northern residential areas.
	• Provide a dedicated lane and sufficient width for bicycles in the road design.
	• Add enough bicycle trip facilities at Glen Waverley station, including lockers and changing rooms.

Strategy 4. Increase the penetration and occupancy rate of shared AV vehicles to reduce peak traffic volume

Objectives	Actions
1. Combine with smartphones to achieve mobility as a service	• Apply smartphone technology to connect various travel modes in order to improve commuting efficiencies, such as online payment of fares, booking and smart recommendations.
2. Increase the travel cost of private cars and single occupancy AVs	• Develop a tiered dynamic per-mile road pricing mechanism (for example: Level 0-4 private cars—elevated surcharge; Single occupancy AVs—base surcharge; Shared AVs—no surcharge).
	• Raise the cost of private cars and single occupancy AVs by collect parking fees, insurance.
3. Promote residents' understanding of shared AVs	• Establish a community platform to provide residents with sustainable transport information and receive effective feedback in real-time.
	• Change residents' negative views on walking, biking and public transportation by promoting the advantages of shared AVs.

Strategy 5. Improve the management of kerb space and parking space

Objectives	Actions
1. Provide sufficient kerb space to meet fast boarding and unloading needs of passengers during peak hours.	• Design proper allocations of kerb space regarding traffic flow, for example, traffic ratio of the Railway North and Coleman street close to 5:5 (City Council, 2014) • Give priority to shared AVs, providing adequate drop off and pick up areas over private AVs.
2. Improve multiple kerb space functions.	• Design kerb space function space in different time periods. The peak period could be used as a basic landing area. Inter-peak and evenings can combine commercial use to improve the vitality of this area and active monitoring.
3. Consider elaborately to the size of parking lots	• Allow the reuse of parking lots in the future as parking requirements decrease. • Design the appropriate width and Length of Parking lots because AV cars can save footprint (Nourinejad, Bahrami & Roorda, 2018).
4. Reduce GWAC's on-street and on-ground parking space to provide extra land for commercial and public space.	• Improve the occupancy of existing parking buildings by providing electronic signal lights with identification.

Conclusion

AV technology has become an unavoidable trend, and a large number of benefits have been identified. By reviewing the trend of AV technology and its applications, AV cars will have a tremendous impact on future urban environments, transportation systems and residents' daily travel. Taking Glen Waverley Station as a case study, many traffic problems exist as of today. Combined with population growth and employment, this report studied the effect of different configurations of AV cars on the space of Glen Waverley station in 2036. By comparing and analyzing three scenarios, results show that AV cars achieve higher space utilization and commuting efficiency. As the most reasonable being in 2036, scenario 3 considers multiple traffic modes and a lot of saved and reused space to promote the vitality of the community and residents' amenities. Moreover, peak traffic flow can be significantly reduced, which can relieve road pressure and facilitate the safe travel of pedestrians and cyclists. Besides, reasonable distribution of kerb space can decline traffic congestion and achieve the smoother traffic flow.

Therefore, based on Scenario 3, the integrated transport plan proposes five strategies to achieve a sustainable transport system for Glen Waverley station in 2036. Shared AVs will be encouraged through multiple actions. The performance of road networks and public transportation will be enhanced to increase the attractiveness of AV cars. A significant amount of released parking space will be given priority, for the benefit of the development of a vibrant community. The management of kerb and parking space will be improved to provide better service. In addition, access to the road network and a safe environment will be designed to assist in the development of walking and cycling travel modes.

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