University of Southern Queensland

Faculty of Health, Engineering and Sciences

The Potential Impact of Autonomous Vehicles on Urban Form and Land Use in Sydney (CBD) — A Case Study

A dissertation submitted by

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Abstract

Autonomous vehicles (AVs) are increasingly being considered the future of road travel and may eventually replace human-driven cars altogether. Scholars argue that with the adoption of AVs that parking requirements will be reduced. The question is what will this land be used for in the future? At the same time there is pressure for further densifications of our cities to reduce urban sprawl, but also concerns regarding providing adequate quality open space in especially city centres.

This dissertation details a mixed method bounded case study of the Sydney Central Business District (CBD) to examine the likely impact AVs will have on parking and how green spaces can be used to fill redundant car parks. Data collection was in two stages. Stage One was a land use survey of existing street parking and open space. Stage Two consisted of a transect to illustrate how the change in land use could transform the area of regained land to meet the requirements for best practice open space design.

The key outcomes of this project are to provide an indication of the viability of a change in land use due to the potential redundancy of parking spaces in the Sydney CBD due the adoption of AVs.

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Nomenclature

ABS	Australian Bureau of Statistics
AV	Autonomous Vehicle
CBD	Central Business District
km	Kilometre
LGA	Local Government Area
m	Metre
NGP	Next Generation Planning
USA	United States of America

Glossary of Terms

Grey Infrastructure: refers to the human-engineered infrastructure for water resources such as water and wastewater treatment systems, piped drainage and reservoirs.

Land Use: Any type of activity, function, or purpose a property may be used for. General land use categories include residential, commercial, industrial, and government (or public facilities). More specific land uses include retail, restaurants, single-family homes, warehouses, offices, and parks.

Liveable: a built environment which supports and responds to people's patterns of living, and is suitable and appropriate for habitation, promoting enjoyment, safety and prosperity.

New Urbanism: An urban design movement aimed at creating compact, mixed-use developments that support the use of public transit, walking and contain a range of housing and jobs. Also see Smart Growth.

Open space: land that has no buildings or other built structures, which is accessible to the public, including green space.

Quality: the standard of something, measured comparatively against things of a similar kind.

Smart Growth: An urban planning movement advocating the development of compact, mixed-use areas that support use of public transit and walking as an alternative to urban sprawl. Also see New Urbanism.

Transect: A geographical cross-section revealing a sequence of physical environments. In reference to the urban metropolis, a transect refers to the varying level of intensity in the physical and social character of different urban contexts.

Urban Sprawl: A term used to describe the pattern of development typically consisting of large lot single-family neighbourhoods at the fringe of an urban area. This type of development typically requires automobiles to travel any distance due to the lack of transportation options and distant services, workplaces, and recreation venues.

Chapter 1: Introduction

1.1 PROBLEM STATEMENT

Many of the studies on Autonomous Vehicles (AVs) have focused on the benefits and negative impacts of the technology, along with the relationship of land use and transport interactions. This dissertation focuses on the gap in the literature pertaining to the impact of AVs land use and built form – and specifically regarding parking. It led to the question: What would the centre of Sydney look like if the predicted reduction of surface parking occurred that the research suggests would result from the adoption of AVs in the future?

1.2 RESEARCH AIMS

The aim of this dissertation is to investigate the impact AVs will have on land use. It will look at the land used for street parking. The research indicates that with the adoption of AVs the requirement for parking will be vastly reduced. The question is how much parking is affected and what will this land be used for in the future? The dissertation will use Sydney Central Business District (CBD) as a case study to conceptualise how a city could look in the future if the land used for parking were impacted as the research suggests.

1.3 JUSTIFICATION

The literature review has highlighted that there is comparatively little research on the impact of AVs on land use, when compared to transportation. Consequently, there is very little investigation on the impact of AVs on parking in real-world cities. Only Lisbon has been examined in detail in this field. Finally, there is no research that goes beyond the idea that parking will be reduced to examine what can be done with redundant parking land. This dissertation therefore proposes to undertake a case study of the Sydney CBD to examine the likely impact the AVs will have on parking in this city, and how green spaces can be used to fill redundant car parks.

1.4 PROJECT AIMS AND OBJECTIVES

This dissertation aims to demonstrate the viability of converting carparks into green spaces, and furthermore aims to assess the likely impact of this change. This will be achieved by conducting a case study on a suburb in the Sydney CBD. In order to achieve this, aim the following objectives are proposed:

- Identify the impact AVs will have on built form in particular – land use.
- Determine how land use will change
- Identify the current provision for surface parking in Sydney CBD.
- Identify the actual amount of surface parking in total area in Sydney CBD.
- Identify the predicted reduction in the parking provision in Sydney CBD.
- Evaluate the future use of parking in Sydney CBD.

1.5 PROJECT IMPLICATIONS

This dissertation has the potential to demonstrate the impact the adoption of AVs would have on a city. It will the show the reduction in the requirement of land needed for surface parking in a city and consider other available uses for this land. To do so, a bounded case study of an urban area will be used. This will be Sydney CBD. The research will fulfil the gap in knowledge on the impact AV will have on built form.

Chapter 2: Literature Review

This chapter presents the exploration of the literature surrounding AVs and Urban Form. The researched literature is organised into overarching categories and the chapter has been structured with the Introduction presented first, followed by the Background, Impact on Built Form, Visioning and concludes with a Summary and Implications.

The literature review was completed using web-based search engines, utilising databases and library registers. Combinations of the terms and synonyms of 'autonomous vehicles', 'urban form', 'land use', 'parking', 'cities of the future', 'built urban form', 'visioning in (urban) planning', 'community visioning', 'future travel', 'autonomous vehicles and land use' and 'sustainable cities' were used. The search generated 30 – 40 papers from the disciplines of planning, geography and transport.

2.1 BACKGROUND

Autonomous vehicles (AVs) are increasingly being considered the future of road travel, with many assuming they will soon replace human-driven cars altogether. While this is unlikely to be the case in the next few decades, urban planners are being urged by federal governments and industry leaders to begin preparing for the rise of AVs as an everyday mode of transport (Benenson et al., 2008; Godoy et al., 2015).

Even now, AVs are being used by Rio Tinto in Western Australia to haul mining materials, and the University of New South Wales is collaborating with a ride-sharing service to deliver a self-driving service to the local area (Accenture 2019). In fact, most new cars on the market have a degree of autonomy, from cruise control to self-parking functions (TechRepublic 2019). This degree of autonomy is only set to become more complex, potentially erasing the need for drivers completely, and cities must begin to prepare for the changes that AVs will bring.

AVs will have an impact on many areas of city living, but one in particular is city parking. Regardless of whether AVs are used for personal use, as ride-sharing vehicles, or to replace public transport, they will have far less need to be parked because they will be capable of cruising without a driver (Soteropoulos et al. 2019).

Therefore, the rise AVs will make many carparks redundant. This will make current existing carparks available for new developments. The question then becomes, what should be done with the extra space? One possibility is open or green space.

Green spaces encourage physical activity in the local population and act as sites for community activities (WHO.INT 2019). Access to nature is also associated with improvements in mental health and well-being for nearby residents (WHO.INT 2019). These spaces also offer sanctuaries for local wildlife and encourage biodiversity, while simultaneously filtering pollution from the air (WHO.INT 2019).

This dissertation will therefore examine the expected impact of AVs, their specific impact on parking, and the potential for transforming parking spaces into green spaces.

2.2 WHAT ARE AUTONOMOUS VEHICLES

AVs are defined as vehicles that can function either partially or completely without a human driver due to autonomous robotic technology (Beneson et al., 2008; Paden et al., 2016). This ranges from vehicles with single autonomous functions such as braking, lane correction, and cruise control, to vehicles that can handle all aspects of driving, including hazard mitigation, simultaneously without human input (NHTSA 2019).

In 2004, one of the most advanced AVs was only able to complete 7 miles of a 150-mile route designed to demonstrate that AVs could be a viable mode of transport. Just one year later, five vehicles successfully navigated the entirety of the route (Defence Advanced Research Projects Agency, 2012). In 2007, the route was updated to mimic an urban environment. This challenge included blocked roads, traffic regulations, and complex manoeuvring. Six cars successfully completed the course (Defence Advanced Research Projects Agency, 2012). Since then, AV technology has advanced rapidly. In 2014, Google reported that their driverless cars had navigated more than 700 000 miles of Californian roads (Anthony, 2014). Due to the speed at which they have been developed, and their advancing capabilities, many consider AVs the future of road travel.

2.2.1 Levels of Autonomous Vehicles

AVs can be classified based on their level of autonomy. As seen in the table below, AVs are generally classified on a scale of 1-5. Level 1 involves autonomous control of a single aspect of driving, while Level 2 involves autonomous control of one or more aspects of driving (SAE International 2014).

In both cases, the human driver is responsible for most aspects of driving and all aspects of dynamic driving, that is, reacting to the dynamic environment. Many modern cars have either

Level 1 or Level 2 automation. For example, Level 1 encompasses cruise control while Level 2 includes self-parking functions.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 1.1: Summary of SAE International's Levels of Driving Automation for On Road Vehicle (SAE International 2014)

This dissertation is mainly concerned with the higher levels of automation, level 4 and 5, where a human driver is minimally required, or not required at all. These are sometimes referred to as Completely Autonomous Vehicles. These types of vehicles are not available for widespread use yet but are expected to become more common as the technology develops. Indeed, some businesses are already using AV's at their work sites (Accenture 2019). Because this technology has the potential to become ubiquitous, it is important to consider the impacts it could have.

2.2.2 Adoption Timeframes for Autonomous Vehicles

Despite the excitement seen in industries and governments about AV technology, experts largely agree that AVs will not become a mainstream form of transport in the immediate future

(Benenson et al., 2008; Godoy et al., 2015). Although they are being used already by some businesses in closed environments, it is expected to be several decades before AVs replace cars on urban streets in a significant way (American Planning Organisation 2017).

As AVs become more common, (Milakis et al. 2018) have proposed three distinct waves of change. First-order changes include alterations to traffic patterns, changes in travel costs, and changes in travel choices. Second-order changes will be more wide reaching, affecting vehicle ownership and ride sharing, land use and urban sprawl, and transport infrastructure. Finally, third-order changes will occur on a global scale, with AVs changing energy consumption, increasing or reducing pollution, improving safety, altering local economies, and contributing to public health (Milakis et al. 2018).

Therefore, even though the impact from AVs is decades into the future, it is also imminent and will touch many areas of modern life. It is worthwhile beginning to consider the changes and problems that AVs will pose now and begin planning accordingly, especially in the light of other urban and societal issues such as densification and urban sprawl.

2.2.3 Uptake of Autonomous Vehicles

AVs are not yet commercially available to the public. This means that researchers can only hypothesise about their uptake and usage. Many studies have attempted to predict how AVs will be used, but these are based on models and simulations, not on empirical data (Milakis et al., 2017; Zhang, 2017).

Miralles-Guasch and Domene (2010) suggest that AVs will only become mainstream in closed environments such as airports and university campuses. Others believe they will come to dominate industries such as mining and agriculture, but not become part of the urban infrastructure (Economist Technology Quarterly 2012).

Others still have proposed that they will replace public transport with a demand-based ride-sharing service (Gelauff et al. 2017). Surprisingly few models predict that AVs will replace private car ownership on a one-to-one basis. The most convincing argument is instead made for a two-fold model where AVs are shared, rather than privately owned, and act to complement existing and future public transport infrastructure (Porter et al. 2018).

The exact impact of AVs will vary based on their uptake. Nevertheless, there are common problems and common benefits to all scenarios, leading to a consensus on the impact of AVs. This dissertation will assume the two-fold model AVs complementing existing public transport because this is the most likely scenario and has the most research to support it (Porter et al. 2018).

2.2.4 Implementation and Policy

Interestingly, when town planners were interviewed about the ways they thought the built environment would need to change to accommodate AVs, very few saw a need to act now for this future technology (Chapin et al., 2016). Fewer still believed it was necessary to implement policies that would guide the introduction of AVs in a direction that produced benefits for society (Fraedrich et al.) These attitudes are understandable given that the effects of AVs are unlikely to be seen for decades and the exact impact is still largely unknown (Accenture 2019).

Nevertheless, Great Britain and some states of the USA are already introducing regulations (The National Highway and Traffic Safety Administration 2019). This gives the industry clear guidelines to work within. AVs could have a largely negative or positive impact, and it has been argued that this will be determined by key governmental decisions and associated regulations. Therefore, preparing for the arrival of AVs should begin now, and should be addressed by every level of government.

2.3 IMPACT OF AUTONOMOUS VEHICLES

The impacts of AVs are expected to be wide-reaching. They are expected to reduce congestion and reduce car-related fatalities by up to 99% (Fagnant & Kockelman 2013). They will likely increase the number of kilometres travelled, but off-set the environmental impact of this by offering ride-sharing services, using electric car technology, and driving more efficiently (Gruel & Stanford 2016). Several case studies have demonstrated that in urban areas, significantly fewer AVs than regular cars are needed to satisfy transportation demands Spieser et al. (2014) and Fagnant & Kockelman (2014).

Moreover, AVs as ride-sharing services are accessible to people with disabilities, the elderly, those who cannot afford a car outright, and other non-driving subsets of the population (Hidaka & Shiga 2018). Because of their many benefits it is likely that AVs will be widely used.

2.3.1 Parking

Once widely used, AVs will alter the urban landscape in multiple ways. Many potential effects have been suggested, but one that is consistently acknowledged is a reduction in parking spaces. Multiple studies affirm that AVs will not have as much need for parking spaces, either because they are being used as a ride-sharing service or because they can cruise without needing human input (Burns, 2013; Zhang, Guhathakurta, Fang, & Zhang, 2015).

Currently, an average car will spend 96% of its life parked (Duarte & Ratti 2018). AVs are expected to spend significantly less time stationary (Duarte & Ratti 2018). As such, it is postulated that many parking spaces and urban carparks will become redundant. These carparks are often positioned in desirable, inner city locations and are usually accessible either by walking or public transport. The rise of AVs could see this land freed for a variety of other purposes and developments. It has been estimated that millions of square kilometers of valuable land could be liberated for developmental purposes (Duarte & Ratti 2018). There are many potentials uses for these spaces, however this dissertation proposes that redundant carparks should be converted into green spaces

2.3.2 Green Spaces

The term “green space” encompasses a variety of natural environments. It includes woodlands, wetlands, forests, national parks, parklands, and sports fields (WHO.INT 2019).The benefits of such spaces in an urban environment are far-reaching.

Green spaces encourage formal and informal physical activity as well as providing space for social interaction and community events (WHO. Euro 2019). They also deliver mental health benefits, including reducing feelings of anxiety, stress and depression (WHO. Euro 2019). Moreover, green spaces have an economic impact. Properties near green spaces increase in value by 5-7% on average (ABC 2014). Finally, green spaces have a positive impact on the local environment and the climate at large.

Green spaces serve as habitats for local wildlife and can increase biodiversity (Leaf 2015). They improve air quality, reduce urban heating, offset carbon emissions, act as carbon sinks, and reduce the severity of flooding (WHO. Euro 2019). Because of the multitude of benefits, they provide, green spaces are an ideal replacement for carparks made redundant by AVs.

2.3.3 Green Space in Sydney

The amount of open green space that Sydney is legislated to provide is 9% of site area for local and district level open space and 15% of site area including regional open space provision. As a result, Sydney CBD currently has 386 hectares of open space. This represents 14.8% of the total land area in the City LGA. The City of Sydney is expecting to add 36ha of open space to the network by 2030 which will increase open space site area to 16.2% (City of Sydney 2016). Consequently, Sydney CBD is meeting it requirements for open space provision. However, given that land in the CBD is of fixed supply and the population is set to

increase it becomes clear that the open space provisions in the future will prove to be a challenge to meet and solutions will need to be reviewed.

2.4 IMPACT ON BUILT FORM

“Built form”, sometimes called “built environment” is a broad term that refers to structures in a given environment that were constructed by humans and which provide the location for daily human activity (Roof & Oleru 2008). More simply, it is “the human-made space in which people live, work, and recreate on a day-to-day basis,” (Roof & Oleru 2008). Built form includes a variety of structures and locations, including buildings, roads, transportation hubs, and parks (Roof & Oleru 2008).

Built form can be more precisely defined when discussing a specific type of location. Urban form is an example of this. Urban form is best defined as “the physical patterns, layouts, and structures that make up an urban centre,” (Anderson et al. 2001). It describes the physical aspects of a city, including buildings, roads, and parks (Anderson et al. 2001).

Urban structure is a sub-set of urban form and describes the arrangement of city structures relative to one another (Batty & Longley 1994). In other words, urban structure defines how land is used within a city, including where buildings, districts, and green spaces are placed in relation to one another (Batty & Longley 1994).

2.4.1 Extent of Research on Land Use (Urban Structure) and AVs

There is currently a wealth of research available that examines the impact that AVs are likely to have on urban structure. However, there are two major issues with this body of research. The first issue is that most of the research is based upon, or consists solely of, models and simulations. Very little research has examined specific real-world cities to estimate the impact of AVs on those cities. The second issue is that much of the research examines the impact that AVs are likely to have on transportation and the associated infrastructure. While valuable, this neglects many of the second order impacts that AVs can be expected to have on other areas of urban form. Notably, there is a comparative paucity of research examining how AVs will change land.

2.4.2 City Centres

A city is loosely defined as any large settlement of humans (Kuper & Kuper 1996). It is often used to describe “urban” areas, as opposed to “rural” areas (Lynch 2008). Cities are

distinguished from rural areas by their density (National Geographic 2019). In cities, there is generally a high density of buildings, businesses, and people in a relatively small space (National Geographic 2019).

Cities can often sprawl for many hundreds, if not thousands, of square kilometres, and the definition of where a city ends can vary. Many definitions include surrounding suburbs, which are characteristically less dense than the city centre. As such, it becomes necessary to talk about the “central business district” (CBD) which is generally considered the heart of the city. The CBD is defined, as the name suggests, as the business centre of the city (Hartman 1950). CBDs are characteristically the densest part of a city, and highly accessible as most main transport routes either start or finish in the CBD (Geography 2019). There is a high density of businesses including shopping centres, commercial offices, and financial and governmental institutions (Hartman 1950). The area is usually highly populated and generally has the highest population per km2 in the city region (Geography 2019). For this reason, land values are also typically high, so any spare land within the CBD is rarely left undeveloped (Geography 2019). High land values mean that land is generally developed “up” in the form of skyscrapers and this makes open spaces such as parks comparatively rare (Geography 2019).

2.4.3 Central Business Districts and Autonomous Vehicles

Due to their density, CBDs are ideal areas to study the impact of AVs, because it is in these areas that AVs are expected to have the largest effect and greatest benefit (American Planning Organisation 2017). Freeing up a square kilometre of land in the CBD will have a much greater impact than freeing up the same amount of land in a rural region. Likewise, congestion is a major issue for cities and not as much for rural centres. Even within cities congestion is often worse around and within the CBD because the CBD is the hub of business within the city (ABC 2014). CBDs are therefore the focus of this dissertation.

2.4.4 Sydney Central Business District

The Sydney CBD is currently the second largest in Australia, and the second most densely populated, behind Melbourne (ABS 2017). It has a population of approximately 17000 that lives within 2.8km² (ABS 2017). A further 227000 people make their way into the CBD daily for work, within 8485 businesses (City of Sydney 2019). Sydney CBD has the classic characteristics of a CBD: it is densely populated with an emphasis on tall buildings and few open spaces, acts as a centre for transportation, and is the key business district within the city limits (Hartman 1950). Unlike other Australian cities that have highly functional public transport

systems, Sydney residents still rely largely on privately-owned cars for commuting and general driving (ABC 2014). While public transport exists within the city, it is over-burdened and unreliable (ABC 2018). AVs could alleviate many of these problems, which means their uptake in such an area is likely to be large. As such, Sydney CBD is an ideal area for examining the impact of AVs in an Australian context.

2.5 IMPACT ON PARKING

What little research that has been done on the impact of AVs on land use has focused primarily on parking, and how AVs can decrease the need for parking in urban centres. The centres of cities are densely packed areas, with car parks taking up valuable space. In Sydney, there are almost 29000 car spaces (Colliers International 2015). The smallest legal car park in Sydney is 2.3m wide by 5m long (for small cars) (Serena, 2019).

This makes the absolute minimum amount of space taken up by car parks in the Sydney CBD as 333 500m², or 82 acres. This is equivalent to 12% of the area of Sydney CBD. This does not consider extra space required for aisles, entries, exits, ramps and stairwells between levels of multistorey carparks. Freeing up even part of this space could have a significant impact on the built form of the Sydney CBD.

2.5.1 Existing Provision for Parking

The greater Sydney region has 43 local government areas, all of which have different requirements for parking spaces when building new buildings (Brodie & Longworth 2010). On average, they require one parking space per dwelling for residential buildings (Brodie & Longworth 2010). However, in the Sydney CBD, the minimum number of parking spaces for new apartment buildings has been removed. This means new apartments do not have to have a car space assigned to them, worsening existing parking shortages.

2.5.2 Existing Problems with Parking

Parking in Sydney is aptly termed a “battle ground” (NSW Govt 2014). Even in the outer regions of the city residents are competing for carparks (Divine 2018). In the CBD, carparks are a valuable commodity and often sell for more than the cost of a house or apartment (Divine 2018). Two spots in the Sydney CBD sold for $475 000, and prices for well-positioned parking spaces regularly reach $200 000 (Divine 2018). Parking is scarce in the CBD and therefore it is in high demand. This leaves the city with two choices: either increase the space devoted to

parking dramatically or find a transport solution that does not require (or requires considerably less) city parking. Sydney CBD is therefore an ideal city in which to explore the impact that AVs could have on parking needs.

2.5.3 Autonomous Vehicles and Parking

Research generally agrees that AVs will reduce the need for parking, especially within city limits. In the USA, nearly 17 000 km² are exclusively used for parking cars (Choi 2019). In many major cities, roughly one third of all land is dedicated to parking (Tal 2019). San Francisco dedicates 301 acres to surface parking alone (Jencek & Unterreiner 2018). In a city such as Los Angeles, which has a similar population density to Sydney, parking consumes 15% of urban land (Diamandis 2015). In Sydney, parking takes up at least 12%. Reducing the need for parking will free up valuable land within city limits that can be re-purposed. In the USA it is estimated that by 2050, AVs will reduce space dedicated to parking by 5700 km² (Jencek & Unterreiner 2018). That equals 5.7 billion m² of prime real-estate

2.5.4 Practicalities

Much attention has been given to the fact that AVs will reduce parking needs within cities, but there is a considerable amount of research also dedicated to how this can be achieved. Firstly, AVs are narrower than conventional cars, and can fit in narrower car parks (Jencek & Unterreiner 2018). AVs do not need space to open doors when parked, because they are able to drop their passengers outside the car park and park themselves (Jencek & Unterreiner 2018). In a similar vein, car parks that house AVs do not need staircases or elevators (Choi 2019). AVs also remove the need to cater for human error in parking because they use very precise navigation technology (Jencek & Unterreiner 2018). AVs can also be parked in by other AVs, in multiple rows, removing the need for an aisle next to each row (Bahrami 2019). All this means AV car parks could have as little as 10cm either side of leeway (Jencek & Unterreiner 2018). AV car parks are conservatively estimated to be 15% more efficient with their use of space (Jencek & Unterreiner 2018). Some sources claim that they could accommodate up to 87% more cars in the same area, compared to conventional car parks (Choi 2019). Moreover, these parking lots could be in less densely populated suburban areas, rather than in CBDs where space is far more limited (Jencek & Unterreiner 2018). All this means that AVs will greatly reduce the need for parking in city centres and may remove such need altogether.

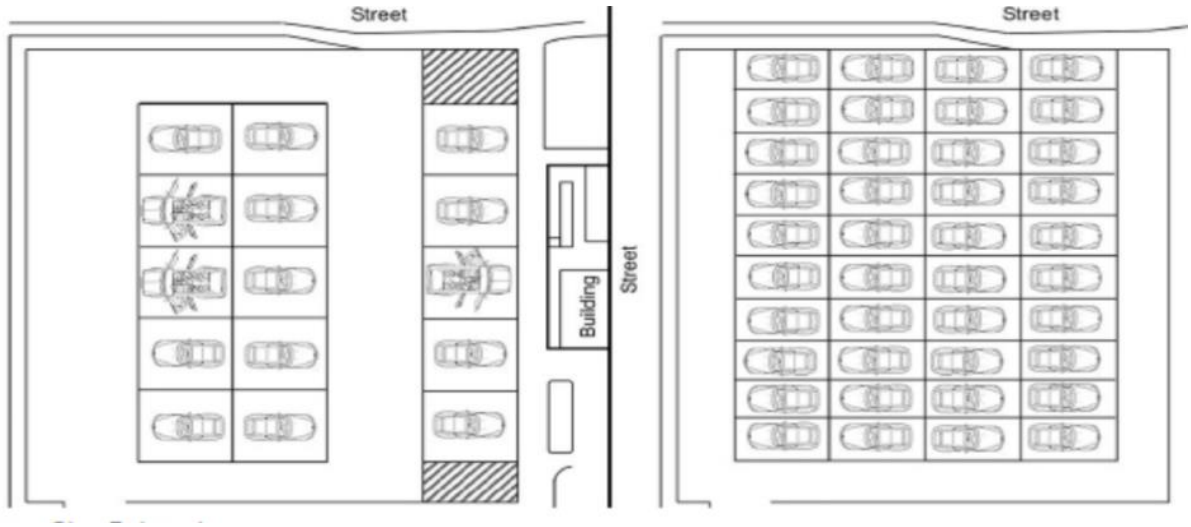


Figure 1.2: How Self-Driving Cars Might Transform City Parking (Bahrami 2019)

2.5.5 Case Study: Lisbon

While many researchers have made sweeping statements about the impact of AVs on parking, very few have examined the potential impact on a specific, real-life city. There is one exception: Lisbon. There has been an extensive case study evaluating the impact that AVs could have on the land use within Lisbon. Lisbon CBD houses half a million people in 100 km² (PORDATA 2014). Although it has a much larger area than the Sydney CBD, the population density is comparable. Sydney's density is 8330 people/km², while Lisbon's is 5000 people/km² (ABS 2017). Lisbon currently has roughly 50 000 off-street parking spaces (International Transport Forum 2015). In this city, it is estimated that a maximum of 26 000 parking spaces would be needed to meet transportation demands if AVs were fully adopted (International Transport Forum 2015). In this scenario, 20% of the kerb-to-kerb street area could be reclaimed for other purposes (International Transport Forum 2015). This model does not factor in the existence of Lisbon's public transport network, which AVs could help to become more efficient (International Transport Forum 2015) When examining the most favourable set of conditions under which AVs could be adopted, as little as 9000 parking spaces would be needed to accommodate enough AVs to meet demand (International Transport Forum 2015). This demonstrates that when examining a real-world city in realistic conditions, AVs could significantly reduce parking by a margin of 50-80%. Given that Sydney has so many issues with parking within its CBD, AVS are not only a viable, but also important, solution to consider.

2.5.6 The Benefits

This dissertation has previously outlined the multiple benefits of adding green spaces to urban areas. Briefly, these include promoting physical activity and community interaction, improving mental health and wellbeing, and providing sanctuaries for wildlife to increase biodiversity (WHO.Euro 2019). However, there are other benefits to greening these spaces. This dissertation will demonstrate that much of Sydney CBD's parking will become redundant with the adoption of AVs. Redundant space in an urban environment is not without its negatives. If this space is opened up for development in ways other than greening, it could be years before projects are started. This will leave the parking lots abandoned for however long it takes for the developer to buy the lot, plan their project, get council approval, and begin and finish building. These projects will then only serve to make the city centre more densely packed with buildings, residents, and commuters. If green spaces are adopted, they can be implemented by city councils, greatly reducing the amount of time the parking spaces stand empty. This is important to reduce the spread of urban blight.

2.5.7 Avoiding Urban Blight

Urban blight, also known as urban decay or urban rot, is a sociological term that describes the process of a previously functioning urban areas becoming non-functional and so falling into disrepair (Badger 2015). Areas affected by blight are often falling to pieces, dangerous, inaccessible to the general public, places where litter collects, a dumping-ground for unwanted items, overgrown with weeds, and covered in graffiti (Badger 2015). Urban blight is described as "contagious", with a single blighted space having a knock-on effect to the rest of the community (Badger 2015).

Urban blight reduces the value of the real-estate that surrounds it, and makes communities less desirable, and more dangerous, to live in (Badger 2015). Urban blight also raises the stress levels of individuals living in proximity to it (South et al. 2015). A 2014 study examined possible solutions to this and found that, while sites of urban decay caused participants' heart rates to increase, similar sites that had undergone a "greening" treatment were able to reduce heart rates significantly (South et al. 2015).

This demonstrates both that urban blight is a major problem if left unchecked, and that it can be eradicated (along with its associated negative effects) by turning abandoned spaces into green spaces. One of the major contributing factors to the development of urban blight is poor or inadequate urban planning (Caro 1974). This makes visioning for the future of Sydney's CBD paramount.

2.5.8 The Philadelphia Example

Philadelphia has a history of successfully fighting urban blight. Issues with urban planning, rent costs, and crime saw a rapid spread of vacant lots in the Philadelphia region, starting in the 1970s (Badger 2015). These lots quickly turned into urban decay hotspots (Badger 2015). A solution was implemented by the Philadelphia Horticultural Society, which brought in soil, put up low wooden fences, and planted grass, trees and plants (Badger 2015). This is a cost-effective way of greening vacant lots, with a price tag of roughly $3 per square metre (Badger 2015). This simple intervention increased property values by up to 20%, decreased gun crime, increased physical activity, and decreased stress in local inhabitants (Badger 2015). Philadelphia is physical proof that green spaces can be used to combat blight.

2.6 VISIONING

To avoid the negative consequents such as urban blight from the lack of planning for the transition to AVs it is important to have a vision for the future. Visioning is the process of developing a goal, plan, or vision for the future (Minowitz 2013). In urban planning, visioning is useful for devising long-term goals for specific regions, and visions often acts as guidelines within which urban planners work (Minowitz 2013). The long-term goals set out by visioning then help direct short-term goals and aid in the development of projects and detailed plans for the area (Minowitz 2013). In this way, visioning can direct the ways in which cities change and grow. Visioning is most useful when it begins broadly and is then translated in specific plans (Minowitz 2013). When visioning is not coupled with action and research, the goals of the vision are often not achieved (Minowitz 2013). However, when done appropriately, visioning can be a highly effective way to plan goals and organise the efforts of multiple stakeholders, including local governments, urban planners, businesses, and individuals (Minowitz 2013).

2.6.1 Visioning Method

Cities are dynamic and constantly move in different directions due to pressures they face. They are constantly evolving and thus any new development is a challenge to the current situation as it can cause a transformation to what was before in unprecedented ways (Madanipour, 2006). Ways to capture these changes in urban design that a city may experience is through Visioning and using a transect and form based coded for how a city should function. A transect is described as ‘an index of diversity’ (Duany, 2002) and offering ‘contemporary ways of envisioning’ (Bohl and Plater-Zyberk, 2006). The Next Generation Planning Handbook is a visioning best practise tool for urban design. It is a set of guidelines

for neighbourhood, street and housing design that is used in South East Queensland. It is intended to help councils plan for future growth, 'making places great for people, and ensuring they can afford to live there'. The NGP guidelines are an adaptation and evolution of the well-known transect planning technique, pioneered by North American new urbanists but also used in some Australian developments (McKeown 2011). The NGP guideline will be used in this dissertation as an assessment tool to examine changes to urban form that result from the change in use of parking to open space.

2.6.2 Visions for Sydney

Just as Queensland urban designers have the NGP Guidelines as a visualisation tool for place making, there are several notable policies that apply to Sydney that offer similarity applicable concepts and strategies for how Sydney's urban environment should look as it approaches the future. The policies and their key themes for a liveable urban environment focus on the recognition that quality urban environments must include for the provision of parks. They recognise and understand that public open space represents a substantial real estate asset for the city of Sydney. The policies and their themes are listed in the following table (City of Sydney 2016).

Table 1.1 Sydney Policies for Liveable Urban Environments

1. The Open Space, Sports and Recreation Needs Study 2016.	
Key Themes	Increased density - allow for more people to live in Sydney and in increasing densities (City of Sydney 2016).
	Healthy living – promotion of health and fitness to reduce rates of obesity and chronic disease in the community, provide mental health benefits and foster individual and community well-being (City of Sydney 2016).
2. Greener Places: Establishing an urban Green Infrastructure policy for New South Wales.	
Key Themes	Create a healthier, more liveable and sustainable urban environment by improving community access to recreation and exercise, supporting walking and cycling connections, and improving the resilience of urban areas (GANSW 2019).
3. Greening Sydney Plan	
Key Themes	Expanding the urban forest (City of Sydney 2012).
	Creating greener streets (City of Sydney 2012).
	Providing more parks and open space (City of Sydney 2012).

	Greening new development and private land (City of Sydney 2012).
4. Sustainable Sydney 2030 - Community Strategic Plan 2017– 2021	
Key Themes	Outlines a plan for **a** green, global and connected city. **Green** with a modest environmental impact, green with trees, parks, gardens and linked open spaces, green by example and green by reputation (City of Sydney 2017). **Global** in economic orientation, global in links, partnerships and knowledge exchange, global and open-minded in outlook and attitude (City of Sydney 2017). **Connected -** easy to get around with a local network for walking and cycling, and transit routes connecting the city's villages, city centre and the rest of inner Sydney (City of Sydney 2017)

2.6.3 202020 Vision

The 202020 Vision project aims to increase green space in urban areas by 20% by 2020 (202020 Vision 2015). This vision brings together the efforts of 29 strategic experts, 200+ organisations and businesses, local industries, Non-Government Organisations, and local and state governments (202020 Vision 2015). It is a highly effective way of co-ordinating the efforts of multiple stakeholders using research-based and practically focused strategies to achieve a single goal. The 202020 Vision recognises the value of green spaces within the community, including improving health and wellbeing, increasing productivity, enhancing community engagement, providing cleaner air and cooler cities, and improving water management (202020 Vision 2015). Although largely visionary in nature, the plan has been incorporated into numerous planning documents, including the Next Generation Planning Guidelines which is designed for urban planners to help them plan for the future growth of cities in south-east Queensland (Council of Mayors (SEQ) 2011).

2.6.4 The Melbourne Example

One city has gone beyond visioning and planning and has begun implementing greening strategies on a large scale. This city is Melbourne, which introduced the "Greening the West" initiative in 2011 (Furlong et al. 2017). Similar to the 202020 Vision, the Greening the West initiative has brought together multiple stakeholders to achieve a single goal - to plant a million trees by 2018 (Furlong et al. 2017). The initiative has been successful in achieving this goal, demonstrating that visioning, when used well, is a powerful tool. Melbourne's western suburbs

have seen noticeable benefits from this initiative, including cooling the region significantly, making it more pleasant to live in, encouraging physical activity, and increasing house prices (Furlong et al. 2017). Sydney CBD could benefit from adopting a similar visioning strategy with a similar goal.

2.7 THE PROPOSAL

This dissertation proposes a concept for Sydney's CBD after AVs have made much of the city's on-street parking redundant. The concept is that on-street redundant parking spaces will be converted into public green spaces. This could range from local parks, to outdoor sports fields, to small nature reserves, depending on the size of the parking lot. With appropriate planning, this dissertation suggests that this vision is not only achievable, but necessary to avoid the negative consequences of empty urban land and provide a liveable urban environment for citizens.

2.8 SUMMARY

Planning for Sydney CBD's future is essential. This is because AVs are likely to cause parking spaces in the CBD to become redundant and abandoned. These parking spaces will then become prime locations for urban blight. Turning these parking spaces in green spaces will prevent the spread of blight, as well as offer a myriad of other benefits. Sydney lacks visions and plans to deal with changes in land use and to encourage greening, especially when compared to other cities. Therefore, Sydney should fund research into developing a vision, with an associated actionable plan, for a CBD where redundant car spaces are turned into green spaces. This vision should be based on the successful components of other cities' greening strategies but should also be based on Sydney-specific research. It is therefore necessary to conduct a case study in the Sydney CBD on the potential impact of AVs on parking, and how green spaces might be used in this context, to help inform the visioning process.

2.8.1 Gap in Literature

There are some gaps in the literature that this dissertation aims to fill. Firstly, there is comparatively less research on the impact of AVs on land use, when compared to transportation. Consequently, there is little research on the likely impact of AVs on parking. In particular, there is very little research on AVs impact on parking in real-world cities. Only

Lisbon has been examined in detail in this field. Finally, there is no research that goes beyond the idea that parking will be reduced to examine what can be done with redundant parking lots. This dissertation therefore proposes to undertake a case study of the Sydney CBD to examine the likely impact the AVs will have on parking in this city, and how green spaces can be used to fill redundant car parks.

2.8.2 Assumptions

This dissertation assumes that AVs will be taken up in a ride-sharing context rather than owned privately. It also assumes that AVs are used to complement existing public transport infrastructure, rather than replace it. This is because this is the most likely way that AVs will be taken up (Shay et al. 2018).

2.8.3 Rationale

Therefore, a case study that examines the potential redundancy of parking spaces in the Sydney CBD would be useful for directing future planning. This case study also needs to consider the third-order effects of redundant parking, in particular converting these spaces to green spaces. This is important for the well-being of the residents of Sydney CBD, and to avoid the spread of blight within abandoned car spaces.

Chapter 3: Research Design

3.1 INTRODUCTION

The research design for this dissertation will be explored in this chapter, with the goal of achieving the aims and objectives stated in Section 1.2 of Chapter 1. The methodology is outlined in Section 3.2; the case study and its justification are discussed in Section 3.3; the study area is explained in Section 3.4; data collection and analysis are described in Section 3.5; limitations, and ethical considerations are outlined in Sections 3.6, and 3.7 respectively. Finally, the methodology is summarised in Section 3.8.

3.2 METHODOLOGY

Kallet (2004) ascertains that a research methodology must outline the specific techniques that are used to identify, select and process information in order to answer a research question. This dissertation will employ a mixed methods methodology, using qualitative and quantitative primary and secondary data. This will be achieved by using a case study. The advantage of the case study approach is that it examines the real-life context of a question or problem. It examines the problem in the context in which it occurs, which means that any results produced directly reflect how the problem unfolds in a given situation. A case study attempts to identify the principles that underpin a particular issue by examining an individual, a group, an event, or a location. In this dissertation, a location will be examined as a case study.

This dissertation will take a mixed methods approach, meaning it will use quantitative and qualitative data including both primary and secondary data. Quantitative data will be collected in the form of a street parking and open space survey in the suburb of Haymarket and will be used to facilitate an evaluation of the impact AVs would have on the amount of parking and the future use of the land. Qualitative data will be collated and collected on the desktop using Google Maps, Google Street View to produce a transect for analysis against the Next Generation Planning Guidelines (NGP) and expected to reveal the impact on urban for and structure. Primary data collected was the amount of on-street parking and open space in the Sydney suburb of Haymarket, measured in m^2. Secondary data was collected on the impacts of AVs for on-street parking using Google Maps, Google Street View, photos and NGP Guidelines.

The literature review presented in the previous chapter has provided an overview of the predicted trends and impacts that AVs will bring to cities. Specifically, it has focused on the

impact of AVs on land use. The trend identifies a reduced need for car parking in urban environments. The questions this dissertation seeks to answer is:

> *If the adoption of AV will reduce the amount of on-street parking how would Sydney CBD look if that area were made available for open space?*

3.3 CASE STUDY

Sydney CBD will be used as a case study to hypothesize how a city could look in the future if the land used for parking was to become available as open space due to the research-indicated impact of AVs. The context will be the CBD of Sydney. This has been selected as there is limited research on the impact of AVs on urban form, especially in Australia, and specifically the impact that the reallocation of land used for parking is likely to have.

3.3.1 Case Study Definition

Case studies are a type of research strategy that examine a real-life situation using contextual analysis. The investigation of a case study is in-depth and focused on a limited number of subjects. In this dissertation, the case study will focus on a location – the Sydney CBD. The major advantage of case studies is the external validity of the results. The data is collected in a real-life context, so results are readily applicable to real-world situations.

Due to their context-based approach, case studies have some defining characteristics: they have a narrow focus, are highly detailed, and can combine objective and subjective data to develop a well-rounded understanding of the question being examined. Case studies are therefore suited to research questions that are inextricably linked to an individual, group, or location. In this case, the research question is linked to the Sydney CBD, so a case study is appropriate. The goal of this, and any, case study is to examine a real-world question to discover underlying relationships and principles, and then to be able to apply these to develop a solution or strategy.

3.3.2 Case Study Justification

As outlined in the introduction, the research is to consist of a single bounded case study. In addition to the reasoning discussed, Tellis (1997) identifies that this method is appropriate in situations where a single case can be used to refute or confirm what has been found by other researchers. For example, in this case the predicted trends of the impacts of AVs identified from international research is to be applied to an Australian context. This is in line with Bryman

(2016) who's view is that a case study refers to a study with a specific location (i.e. Sydney CBD), with an emphasis on an investigation within a particular setting (land use – parking).

The justification for using a single case study approach is that it seeks to answer the research questions of this study within a specific set of circumstances (condensed urban environment) and provides an in-depth investigation to those particular circumstances as stated by Habib et al. (2014). Case studies limit the scope of a study in order to increase its depth. This is because the purpose of case study research is not to draw conclusion for the wider population, but to gain a deep understanding of a specific context (Farquhar 2012). Similarly, Creswell (1998) agrees it is to report "lessons learned from the case".

Case studies are still considered empirical research because they involve data collection and analysis. Case studies are strengthened by their ability to incorporate multiple types of data, including primary and secondary, and qualitative and quantitative. This allows research findings to be "triangulated", which is examining a phenomenon from multiple perspectives. Triangulation can increase the robustness of the results.

To establish an answer to the research question, this dissertation will utilise a qualitative bounded case study methodology. Defined by Creswell in 1998, a qualitative bounded case study methodology is one which is confined to a time and a place to allow the researcher to make in-depth enquiry into the subject of the study.

Baxter and Jack (2008) agree it is an appropriate methodology when the focus of the study is to answers questions of "how" and when the context is important to the phenomena being studied. In this dissertation it is being determined "how" AVs will impact land use (parking) and in determining this the context of a geographical location is important.

The context will be the CBD of Sydney. This has been selected as there is limited research on the impact of AVs on urban form and specifically the impact that the reallocation of land used for parking will have.

3.3.3 Single Case

Case studies can be conducted singularly, or as part of a series. A single case study is the most fundamental unit of research and can be used as a foundation upon which future research is built. Even in single case studies there are several types of research that can be undertaken. One such type is exploratory case studies. An exploratory case study is used when there is a lack of preliminary research in a particular field or area (Mills 2010). They are often the first step in the research process when very little research exists because they are able to investigate using multiple sources of data to give a complete picture of the situation

(Yin 2003). They can be used as the foundation for future research and their findings are frequently used to guide future studies (Mills 2010).

This dissertation will use a single exploratory case study. This is because there is very little research into the impact of AVs in an Australian context. The goal of this study is to examine what potential impacts could be, given Australia's existing infrastructure. Using a single case study approach allows the research question to be answered within a specific set of circumstance and provides an in-depth investigation into those particular circumstances. This is an approach endorsed by Habib et al. (2014), and the goal is that the case study will explore the current parking situation to inform future research and future planning for cities.

An Australian city was chosen because there is little research into the impact of AVs in an Australian context. A city was chosen over a rural or remote region because of the greater pressure of population density and population growth it is to suffer in the future. The high density of the city and its associated land scarcity also means that freeing up any parking space could have a significant impact on the local population. This is not as true in rural or remote regions where open land is widely available. The goal of this dissertation is also to examine the impact of AVs on urban form and structure, and this is more readily observable in a CBD compared to a rural or remote area with less infrastructure.

3.3.4 Bounded Case Study

To establish an answer, this dissertation will utilise a bounded case study methodology. A bounded case study is defined by Creswell (1998) as a qualitative methodology that is confined to a time and a place to allow the researcher to make an in-depth enquiry into the subject of the study. Baxter and Jack (2008) agree it is an appropriate methodology when the focus of the study is to answers questions of *"how"* and when the context is important to the phenomena being studied. In this dissertation it is being determined *"how"* AVs will impact land use (parking) and in determining this the context of a geographical location is important.

A case study is bounded when the research has clear and definite research objectives that focus the research and limit its extent (Creswell, 2007). This prevents the case study from becoming too large, losing its focus, being unable to answer the original question, or continuing for too long. Boundaries prevent these scenarios, so are useful tools when conducting a case study. There are several ways to bind a study, as listed below (Creswell, 2003; Stake, 1995; Miles & Huberman, 1994):

- By time and place
- By time and activity
- And context

Boundaries ensure the study has a reasonable scope to answer its question without exhausting resources. It is a similar process to developing inclusion and exclusion criteria in experimental research (Yin 2003). However, boundaries define breadth and depth of a study, not simply the sample population.

In order to limit the variables, avoid dilution of the analysis and provide the required depth to facilitate the best answer to the question Farquhar (2012) regards a single bounded case study methodology as most appropriate for this type of study. Merriam Stake and Yin (2009, 2006 & 2014) state that binding a case study is essential, as this focuses, frames and manages the data collection and analysis and involves being selective and specific in identifying the parameters of the case. As a result, the bounds of this dissertation are first by place: Urban – being Sydney CBD and a suburb located in the CBD being Haymarket using the local government area boundary. The second bound is by time: September 2019 and finally the third bound is by definition and context: AVs at Level 5 adoption. These were established due to outcomes from the research literature, pilot study and time constraints for dissertation.

3.3.5 The Sampling Strategy

The dissertation will use purposeful sampling, which is used in qualitative research. Purposeful sampling chooses the sample intentionally, by identifying information-rich samples and selecting them for study (Gruel & Stanford 2016). This process allows an efficient use of limited resources in order to yield the most informative results (Gruel & Stanford 2016). In this way, purposeful sampling helps to achieve depth of understanding.

This dissertation will use purposeful sampling. The sampling framework is Sydney CBD, and the purposefully selected sampling area is Haymarket. Haymarket was selected for these reasons - its geographic location being inner-city and central within Sydney's CBD. The suburb has both types of land use being surveyed such as a variety of on-street parking and open space. Haymarket is the suburb with Sydney's highest population density along with having the highest predicted population growth for future. The land size of the suburb is small and has ease of access for the researcher.

3.4 THE STUDY AREA

Sydney is the capital city of New South Wales and is the most populous city in Australia (Alessandrini et al. 2015). It is located on the mid coastline of New South Wales. The main commercial centre of Sydney is called the Sydney Central Business District (CBD). In 2016, the population of Sydney CBD was over 17 000 people, in an area of 2.8km^2 Alessandrini et

al. 2015). Its population density is 6160 people/km^2. Each day, over 220 000 people commute into the Sydney CBD for work (City Of Sydney 2012). The Sydney CBD is the major financial and economic hub in Australia and is an important centre for Asia-Pacific trade in the region (City Of Sydney 2012). Boundaries of the CBD can be seen in the map below.

Figure 1.3: Sydney LGA Boundary (Profile.id, 2019)

The Sydney CBD boundaries run from Circular Quay in the north to Central Station in the South. It is bounded in the east by a group of parks including Hyde Park and The Royal Botanic Gardens, and in the west by Darling Harbour (ABS 2017). The Sydney CBD is under the governance of the City of Sydney local government.

The Sydney CBD is densely populated with mostly high-density buildings and very few open spaces (Hartman 1950) This makes it ideal for examining the potential impacts of increasing open green spaces on a local population. Other capital cities in Australia share these characteristics, but Sydney is particularly well-suited to the aims of this dissertation because it lacks an adequate public transport system in the CBD. In Sydney the public transport system

is overburdened and unreliable, meaning that many residents and commuters instead opt to drive their cars into the CBD (ABC 2018). This leads to hours of congestion and means that many open spaces are devoted to car parking. AVs are most likely to have the biggest impact in the Sydney CBD for these reasons. They can alleviate the public transport problem while simultaneously reducing the need for parking.

The entire CBD of Sydney is too large to be examined in a single study, so instead a smaller, representative region has been selected as a case study. This region is Haymarket, a suburb on the southern side of the Sydney CBD with an area of 0.4km^2 (ABS 2017). This is a typical Sydney CBD suburb and has many features shared with other CBD suburbs. This includes markets, restaurants, boutiques, specialty stores, and a cinema (ABS 2017). There is also a significant residential population, with over 7000 people residing in Haymarket 99.8% of residential buildings in Haymarket are flats, units, or apartments (ABS 2017)This is in keeping with most of the Sydney CBD. Therefore, Haymarket is a representative sample. The boundaries of Haymarket can be seen in the map below.

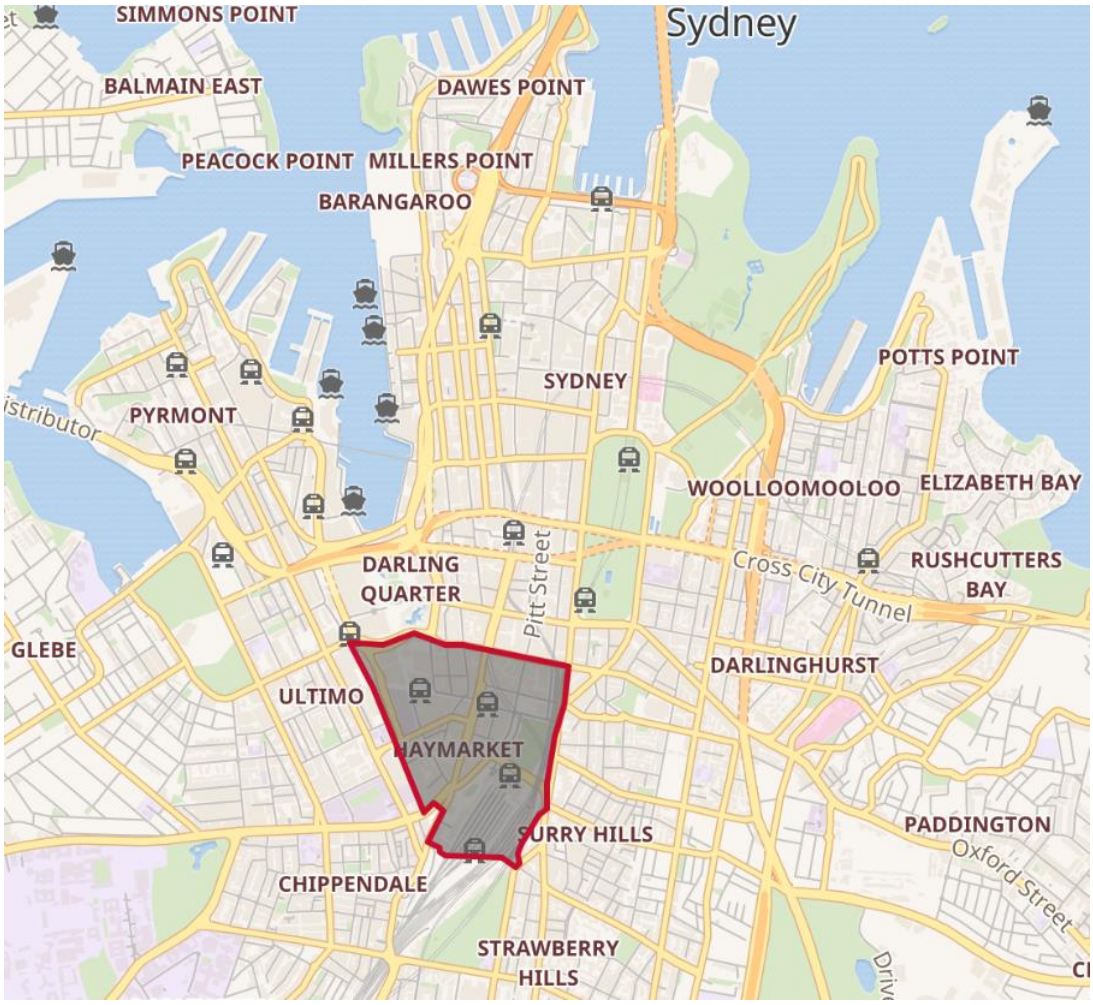


Figure 1.4: Haymarket LGA Boundary (Profile.id, 2019)

The justification in choosing Haymarket as the study area is due to its population density. The 2018 Estimated Resident Population for Haymarket is 8 476 people, with a population density of 162.82 persons per hectare, making is Sydney's most densely populated suburb. In twenty years (2036) it is predicted to grow to 23 140 people per km². This is the greatest increase for any area in the Sydney CBD with an expected population increase of 27%.

Therefore, Haymarket will be under a lot of pressure to house the population in a quality urban environment. It will be difficult to provide access to open space for the future population given the small area of land it takes up and that there will be no new supply of land to the dense built environment. These elements combined make it ideal to examine the impact of the land use change from parking to open space.

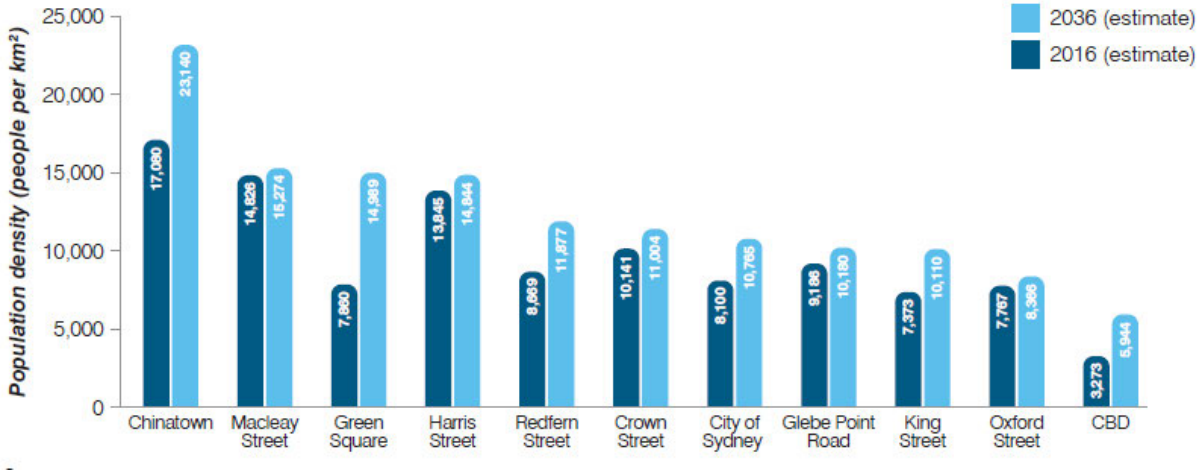


Figure 1.5: Population Density of Sydney CBD (City of Sydney 2016)

There are 37 streets in Haymarket – however not all of them provide on-street parking due to their central CBD location. The streets without parking are mostly the main arterial roads intersecting the city such as Pier St as seen below.

Figure 1.6: Freeway of Pier Street (Google Street View, 2019)

Or they are laneways that have become pedestrianised such as Tumbalong Boulevard as seen in the following figure.

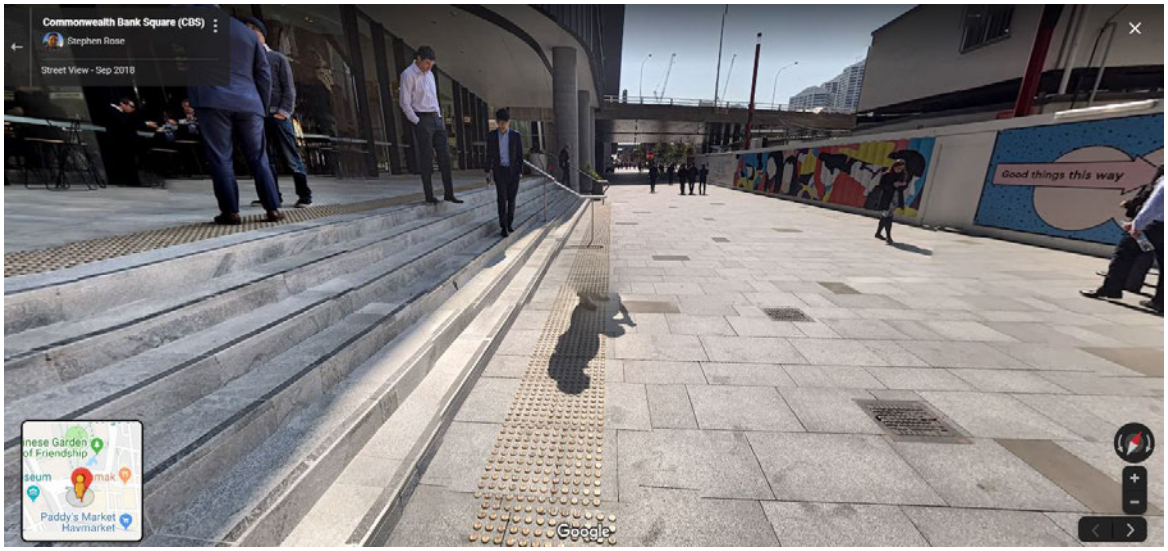


Figure 1.7: Pedestrianised Tumbalong Boulevard (Google Street View, 2019)

The streets identified without parking are Broadway, Lee St, Bijou Ln, Pitt St, Harbour St, Dixon St, Tumbalong Blvd, The Goods Line, Cunningham St, Kimber Ln, Rawson Pl, Hay St, Eddy Ave, Factory St, Pier St, James Ln, Zollner Cct and Steam Mill Ln.

Whilst the streets identified with on-street parking either timed and/or paid are: George St, Thomas St, Thomas Ln, Quay St, Parker St, Sussex St, , Ultimo Rd, Castlereagh St, Little Pier St, Little Hay St, Ambulance Ave, Railway Colonnade Dve, Campbell St, Barlow St and Valentine St.

Goulburn St and Elizabeth St and Chalmers St will not be included for simplicity as the Haymarket LGA boundary bisects these streets. This determination of streets with and without parking has been made from Google Maps, Google Street View and with a physical visual check at the location to confirm.

3.5 DATA COLLECTION AND ANALYSIS

This dissertation involved several steps. The first step was to develop a methodology and approach to the task. The second step was to conduct a pilot study to evaluate the methodology and approach, and to fine-tune the methodology. This was followed by Stage One, a land use survey that evaluated the area of street parking on designated streets. Finally, Stage Two was conducted, in which a transect was made.

There were several stages of refinement of the method. Initially, Google Maps was used as the main data source for on-street parking, but the information provided was not up to date. One possible solution was to retrieve the number of car parking spaces from the City of Sydney and the Roads and Maritime Services, but the time constraints on the dissertation meant that this was not feasible. Another solution was to measure the length of the street (with timed and/or paid) street parking to determine a total area of street parking.

This involved a physical count in the study area. This was the solution that was most feasible given the constraints of the dissertation, and as a result a simple calculation method was developed based on total parking lengths and information from Council documents. This can be found in Appendix C.

Several categories of data were collected during the site visit. This included, day, date, start and end time of survey, parking restrictions, length of parking, parking set back from intersections and type of parking (parallel, angle).

3.5.1 Data Sources

The primary data was collected in-person by taking measurements in the designated streets. Secondary data was retrieved from a variety of sources which were statistical data of the social economy, population data, basic street maps, Google maps, Google street view and the City of Sydney website for “Map of Parking Meters in the City”.

Statistical data provided insight into the density and built form of the case study region. Basic maps were used because they are powerful tools for displaying urban structures and city layouts. Google maps were used because they are interactive and give information on transportation, land use, built form, and natural open spaces. Google street view was used to

visualise the designated streets before visiting in person to ensure they were appropriate for the purposes of this dissertation.

Contextual mapping using a transect approach allowed complex and heterogenous landscapes to be classified and compared. The City of Sydney website was used to estimate the parking situation in certain streets in order to aid appropriate street selection.

3.5.2 Equipment

The equipment used to facilitate the dissertation was mostly from the desktop using basic maps, Google maps, Google street view, QGIS 3.8.1 Software and AutoCAD 2013 software. Physical equipment included a camera – Apple iPhone 5 and a trundle - Craftright Lightweight Measuring Wheel.

3.5.3 Pilot Study

The goal of the pilot study was to determine if the proposed methodology was able to answer the research problem. The pilot study also identified weaknesses in the methodology that could be fixed before the main study and was useful for narrowing down the streets selected for inclusion in the final dissertation.

The pilot study was conducted on August 29, 2019 to test the validity of the methodology and to determine the locations for the final study. The pilot study was run as a desktop study.

Initially, mesh blocks, the smallest unit of geographical area defined by the Australian Bureau of Statistics, were used to identify potential areas of study. However, this proved ineffective because mesh blocks were frequently too small and had boundaries that ran down the middle of streets, dividing a single street into two different blocks. Instead, it was decided to examine streets within a local government area and based on suburbs rather than mesh blocks.

During the pilot study, Google Maps and Google Street View were used to identify potential neighbourhoods in the Sydney CBD that would make appropriate case studies. Once Haymarket was selected, Google Maps Aerial View was used to determine a shortlist of streets that would be appropriate places to evaluate parking. Initially the goal of the main study was to examine four different areas within the study area that had different parking situations. The hypothesised areas and types of parking were a street with designated surface parking, a street with no designated surface parking, a street in a mixed-use area, and a street in a residential area. The goal of examining four different areas was to demonstrate that any proposed solution could be applicable to multiple areas of the Sydney CBD. The pilot study therefore attempted to identify suitable streets in each of these categories.

The pilot study revealed that there was insufficient electronic data available on all four street types. Identifying each street type would therefore require in-person surveys and a large amount of time. Therefore, the pilot study found that it would not be possible to identify streets of all four types within the timeframe of this dissertation. Instead, a single type was chosen streets with on-street parking. The pilot study revealed that there was adequate information available to identify these types of streets and to make a short list of streets that would be appropriate for examination.

A single exemplar street was identified – Sussex Street in Haymarket. The methodology of the main study was tested by doing a desktop study to see if the methodology would produce viable results. An aerial map was created to estimate the area dedicated to street parking. A transect was then developed to demonstrate the form of the street. Another transect was then proposed, turning the on-street parking into green spaces. Below is the data collected on Sussex Street showing the area of on-street parking using desktop study methods.

Below is an aerial map created by the author in AutoCAD from Google Maps, Google Street View and City of Sydney Maps taken from their website. It shows the approximate area dedicated to street parking on Sussex Street. In the dissertation, this study would be conducted by taking measurements in person. The figure below shows the area and location of on-street parking in Sussex Street, Haymarket.

Figure 1.8: Sussex Street On-Street Parking (Author, 2019)

The following figure shows a transect taken through Sussex Street which was developed to show the urban form of Sussex Street.

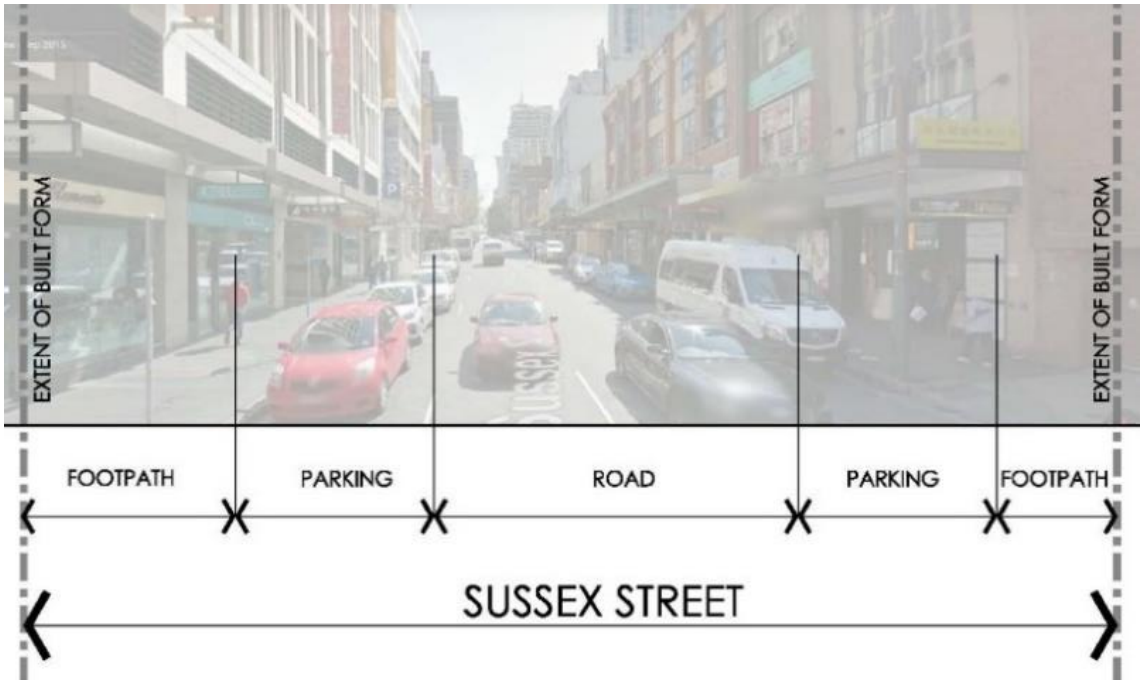


Figure 1.9: Sussex Street Transect (Author 2019)

As seen below, the transect was then modified to show what could be done with redundant parking spaces by turning them into green spaces.

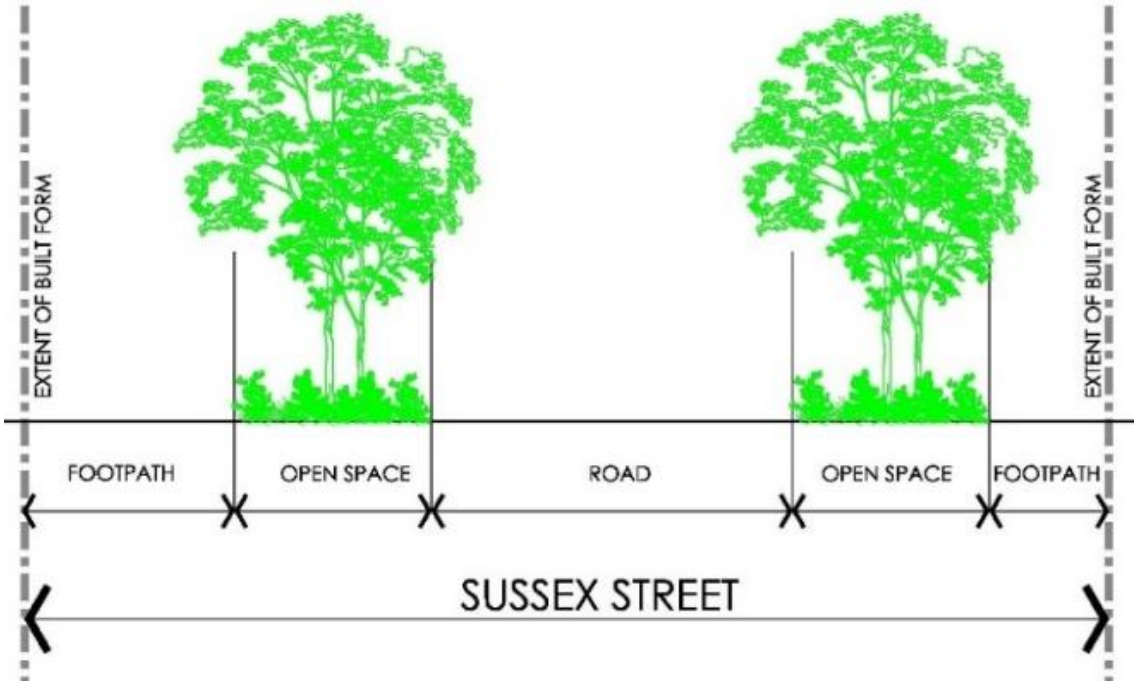


Figure 1.10: Sussex Street Proposed Land Use Change (Author 2019)

The pilot study altered the unit of study from mesh block to local government areas. It reduced the number of parking types from four to one: streets with on-street parking. It helped to identify the streets that would be analysed in the main study. Finally, it determined that a desktop version of the methodology would only be viable for the Stage Two - transect portion of the dissertation.

3.5.4 Stage One: Land Use Survey

A land use survey is a study of the ways in which a particular piece of land is being used at a particular point in time. These sorts of surveys have often been used to inform urban planning (Breheny and Batey, 1981). A land survey involves analyzing primary and secondary data, as well as quantitative and qualitative data, to help the researcher to understand the study area. Surveying can be used in urban settings to examine land use, built form, traffic patterns, and parking configurations (Lagopoulos, 2018). This makes it an indispensable tool for urban planning, especially when that planning involves streets and parking. Surveying is generally the basis for all effective urban planning. Surveying has been especially useful in examining patterns of land use in urban areas, where land is often limited (Akimoto, 2009; Hirt, 2018; Hirt and Stanilov, 2009; OECD, 2017). Urban land use surveys are often the starting point for future planning because they demonstrate how the land is currently being used which informs researchers on how the land might be more effectively used in future. Therefore, there is a tendency for land use surveying to be done before urban planning, with the goal of analysing the study area. This dissertation will follow that approach.

The first step in the land use survey was to identify, collect and review all background data and reports. Next, existing data on the total amount of on-street parking in m^2 in Haymarket needed to be collected. Likewise, the amount of open space in m^2 in Haymarket needed to be collected. The pilot study showed that using a desktop study was an insufficient means for collecting this data, which meant that on-street parking data needed to be physically counted.

An in-person count and measure of the length of the streets and the extent of on-street parking was undertaken in Haymarket to establish the amount of car parks available in the study area. The type of parking measured was on-street timed and/or paid parking. This study did not include parking that was residential, underground, covered, or privately owned. It did include timed loading zones, clearways, and work zones that convert into parking at set times.

The first step was to identify the streets in Haymarket that had the appropriate type of parking. The Map of Parking Meters in the City on the City of Sydney's website was used to locate and manually mark on a map the streets that had paid and/or timed on-street parking. This was cross-referenced with Google Maps and Google Street View to eliminate the streets with no

parking. This was then confirmed via a site visit to Haymarket to confirm each chosen street. From this information a map was drawn to scale using AutoCAD software. Several Google Maps were scaled and imported into AutoCAD for an underlay to trace over to produce a base map to scale of the study area.

The second step was to visit the site to manually count the parking by measuring the length and location of parking on that street. Parking signs were used to mark the start and end of the parking type needed. The streets were measured using a trundle meter (specifications of which can be found in Appendix B). The location and dimensions of parking on the streets were marked on the map. Each street in the suburb was walked to confirm the results of the desktop study.

The final step was completed at the desktop where the results from the site visit were drawn to scale onto the CAD based map to enable accurate area measurements to be taken.

3.5.5 Stage Two: Transect

A transect is a useful tool in urban design research and is used as evaluation and assessment system for design (Emerson, 2007, Low, 2010, and Thadani 2011). It records land use in a visual descriptive approach and categorises it by taking a cross-section through area and overlaying zones to identify how the land is used in each section of the cross section. A transect diagram therefore allows an accurate analysis of land use and can be used to hypothesis alternative land use. (Coyle, 2011) By triangulating the findings from the base map with qualitative data a representative transect is generated to facilitate the assessment and discussion of the results to answer the research questions of….

"What impact AV will have on built form?"

The Transect will be used to demonstrate how the change in use would look from both an aerial view and a section view of the suburb. Stage Two will discuss the impact from change in land use from on-street parking to open space on the urban form using NGP Guidelines.

A Desktop method using AutoCAD and Office software is used to generate a transect and new data in the form of maps and tables from the land use study and Google Street View. The transect is then used to examine the impact that a land use change from on-street parking to open space may have on the CBD urban form and structure. This is done by using the NGP Guidelines which is considered a best practise tool to guide urban environments to visually analyse and understand the impacts on urban design qualities and any resulting urban morphological changes.

3.5.6 Data Validation

Primary data collected during the land use survey was used to validate secondary data to ensure secondary data was both current and relevant. Sources of secondary data such as Google Street Images that were found to be out-of-date in the pilot study were replaced by primary data.

3.6 LIMITATIONS

There were several limitations to this dissertation. Firstly, detailed typography was needed in order to obtain greater accuracy. This was not achievable due to time and resources allocated to the dissertation but would be useful in future research to improve the accuracy of area measurements.

Secondly, Google Maps was used as an underlay for a trace to measure the width of footpaths, roads, and overhead awnings. These could be measured with greater accuracy using in-person measurement methods. Thirdly, there were significant time constraints on this dissertation meaning that the amount of data that could be obtained was limited. More data collection would provide greater accuracy and robustness to the findings and is advisable in future research.

The major assumption of this dissertation was that parking was 5.2 x 2.6m as a band, and changes for kerbs and footpaths were not considered. This was assumed because of the time constraints of the dissertation, but future research should endeavour to avoid this assumption to have more accurate results.

3.7 ETHICAL CONSIDERATIONS

The dissertation was fairly low impact and did not have much effect upon the local community. Nevertheless, there were several ethical considerations to be evaluated when conducting the case study. Firstly, the study was conducted on public streets. These streets are public property and the study did not impinge upon other members of the public's use of the streets. Therefore, it was important not to hinder the passage of cars on the streets or prevent them from using the public parking available. Secondly, the privacy of other members of the public was protected. Photographs were taken during the course of this dissertation so ethical consideration was given to ensure that the public's privacy was protected. Considering this, the author avoided taking photographs while members of the public were in the vicinity and tried to avoid taking photographs that contained members of the public. When this was

unavoidable, the faces of members of the public were obscured. Likewise, the number plates of vehicles in the photographs were also concealed.

3.8 CONCLUSION

This chapter has outlined the research design of this dissertation and the reasoning and theory behind the design. It has detailed the methodological approach and justified methodological choices when necessary. It has furthermore presented the approach to data collection and analysis, as well as the results of the study. This dissertation was a single exploratory case study that used both quantitative and qualitative data. The limitations, hazards, and ethical considerations of this study were also presented.

Chapter 4: Results & Discussion

4.1 INTRODUCTION

This section will combine the results and discussion chapters together. It is divided into the stages that the dissertation was undertaken. The first part of this Chapter will focus on Stage One being the land use survey. This stage of the dissertation involved the collection of quantitative data in the form of a land use survey to establish the supply of the existing on-street parking that is available in the study area of Haymarket in the Sydney CBD. The second part of the chapter will provide results in qualitative form for Stage Two of the dissertation. This consists of a visual and descriptive analysis using NGP Guidelines to examine the potential impact AVs may have on the urban form and structure in the study area.

4.2 STAGE ONE – LAND USE SURVEY RESULTS

The results of the land use survey undertaken are provided in the table below. The table identifies all the streets in Haymarket and the area amount of on-street parking that is provided in that street.

Table 1.2: Land Use Survey Results

George St
Lengths of Parking
27m
21m
61m

Total Length = 109m
Total Area [14.04 x109] = **1530.360m²**

Thomas St
Lengths of Parking
28m
46m
32m
16m
30m

Total Length = 152m
Total Area [14.04 x152] = **2134.080m²**

Thomas Ln
Lengths of Parking
11m
23m

Total Length = 34m
Total Area [14.04 x 34] = **477.360m²**

Quay St
Lengths of Parking
28m
82m
26m
9m
12m
106m

Total Length = 263m
Total Area [14.04 x 263] = **3692.520m²**

Parker St
Parallel parking
13m
31m
24m
Angled parking
73m

Total Length = 141m
Total Area [14.04 x 141] = **1979.64m²**

Pitt St
Lengths of Parking
87m

Total Length = 87m
Total Area [14.04 x 87] = **1221.480m²**

Sussex St
Lengths of Parking
25m
23m
35m
12m
29m
31m

Total Length = 155m
Total Area [14.04 x 155] = **2176.200m²**

Ultimo Rd
Lengths of Parking
34m
65m
73m
39m

Total Length = 211m
Total Area [14.04 x 211] = **2962.440m²**

Castlereagh St
Lengths of Parking
12m
12m

Total Length = 24m
Total Area [14.04 x 24] = **336.960m²**

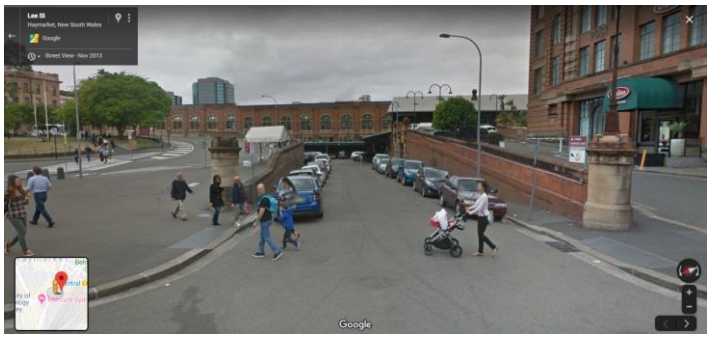
Little Pier St
Lengths of Parking
15m

Total Length = 15m
Total Area [14.04 x 15] = **210.600m²**

Little Hay St
Lengths of Parking
12m
12m
14m
14m
12m

Total Length = 64m
Total Area [14.04 x 64] = **898.560m²**

Ambulance Ave
Lengths of Parking
43m
42m



Total Length = 84m
Total Area [14.04 x 84] = **1179.360m²**

Railway Colonnade Dve
Lengths of Parking
173m
11m
70m

Total Length = 254m
Total Area [14.04 x 254] = **3566.160m²**

Campbell St
Lengths of Parking
60m
15m
50m
41m
16m

Total Length = 182m
Total Area [14.04 x 182] = **2555.280m²**

Barlow St
Lengths of Parking
49m
25m

Total Length = 74m
Total Area [14.04 x 74] = **1038.960m²**

Valentine St
Lengths of Parking
38m
16m
11m
16m

Total Length = 81m
Total Area [14.04 x 81] = **1137.240m²**

Broadway
No parking

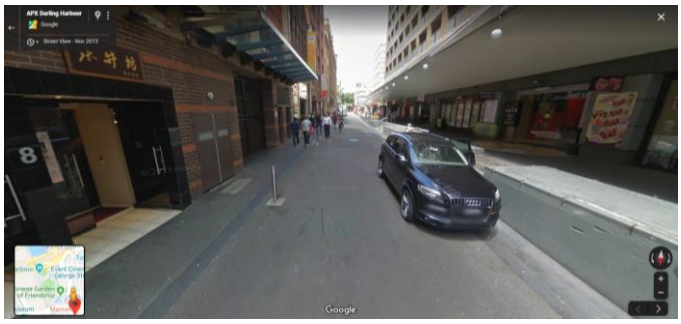
Lee St
No parking

Bijou Ln
No parking

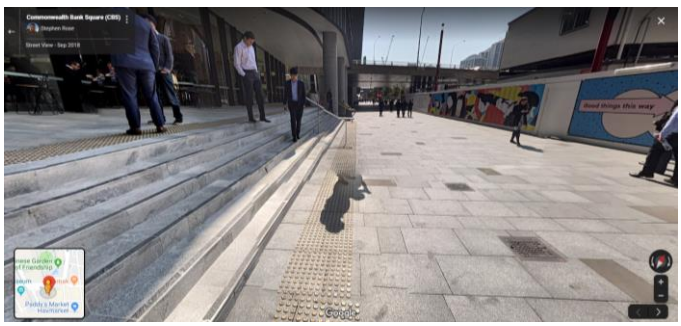
Darling Dr
No parking

Harbour St
No parking

Dixon St
No parking

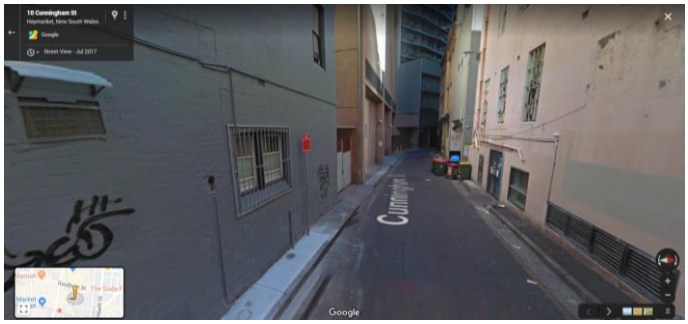


Tumbalong Blvd
No parking

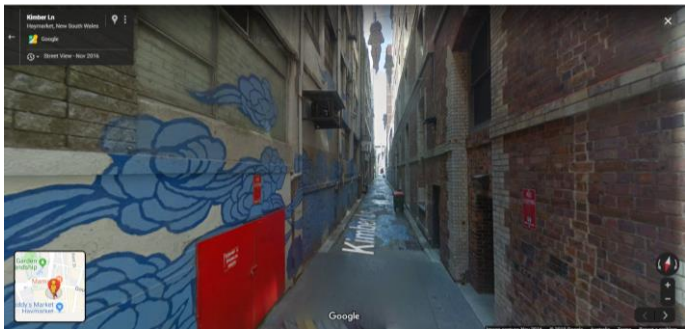


The Goods Line
No parking - pedestrian

Cunningham St
No parking



Kimber Ln
No parking



Rawson Pl
No Parking
Has been a change in use - is now light rail.

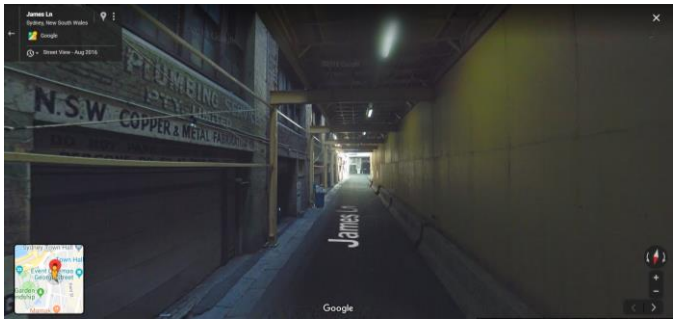
Hay St
No parking

Eddy Ave
No parking

Factory St
No parking

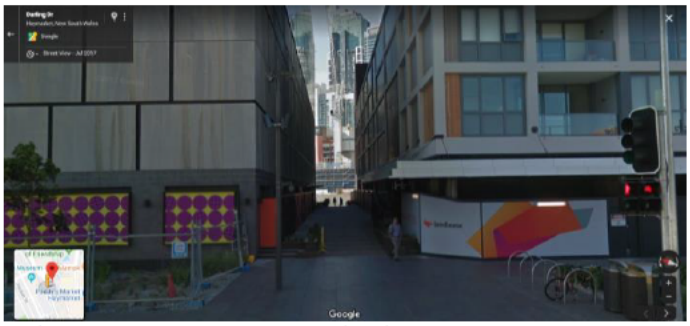
Pier St
No parking

James Ln
No parking



Zollner Cct
No parking

Steam Mill Ln
No parking



Note: All images from Google Street View

Note: Area is calculated using Standard Car Park Dimensions as per Section 4 - City of Sydney DCP as 2.6m x 5.4m = 14.04m² - see Appendix D for calculation.

Table 1.3: Area Results for On-street Parking in Haymarket

Street	**Area (m²)**
George St	1530.360
Thomas St	2134.080
Thomas Ln	477.360
Quay St	3692.520
Parker St	1979.640
Pitt St	1221.480
Sussex St	2176.200
Ultimo Rd	2962.440
Castlereagh St	336.960
Little Pier St	210.600
Little Hay St	898.560
Ambulance Ave	1179.360
Railway Colonnade Dve	3566.160
Campbell St	2555.280
Barlow St	1038.960
Valentine St	1137.240
Total area of on-street parking = 27097.200 m²	

The results show that the amount of area taken up by on-street parking in Haymarket is 27097.200m² (6.69 acres). Rounded to the nearest metre this results in 27097 square metres which is used for the following discussion. The results above have been added to the map below. It shows the location and extent (length and area) that on-street parking occupies in the suburb.

Figure 1.11: On-street Parking Locations in Haymarket (Author 2019)

4.3 DISCUSSION

Studies undertaken in overseas contexts examining the potential impacts on parking resulting from Level 5 adoption of AVs in cities have shown space savings on a large scale. For

example; (Jencek & Unterreiner 2018) states that San Francisco currently dedicates 1 222 200m² to surface parking and Los Angeles, which has a similar population density to Sydney, parking consumes 15% of urban land (Diamandis 2015). Similarly, Lisbon cited that, 20% of the kerb-to-kerb street area could be reclaimed for other purposes (International Transport Forum 2015).

To compare this to the results obtained from this dissertation within the Australian context, the total for the amount of land dedicated to on-street parking is a lot less. The results show that the total amount of land available is 27097m² (a lot smaller than San Francisco amount of 1 222 200m²) where it is only 2% of the amount claimed to be saved. This is due to a few reasons. The first most obvious reason is the type of parking that is included in the studies. This research only looks at on-street surface parking and doesn't not include parking lots above ground in the CBD which some of the studies cited may have included under their definition of parking. The second reason may be due to the City of Sydney's push towards public transport use in the CBD. This is done by introducing the Light Rail to the CBD which has resulted in a loss for on-street parking, the spread of car sharing where parking spaces have been designated for this use and not included in the parking count for this dissertation and the development requirement that new projects in the CBD are not required to provide parking. These combine in a less amount of parking in the Sydney CBD and result in the smaller area of land available for on-street parking.

4.4 THE PROPOSAL

This dissertation demonstrates that when examining a real-world city in realistic conditions, AVs will reduce on-street parking in the Australian context by an amount of 27097m². This amount of area although less than international studies is still significant especially within a CBD where any land is extremely valuable and scarce. This dissertation proposes that the land saved from being used for parking due to the adoption of AVs to be used for open space.

4.4.1 Open Space

There are important reasons for proposing the change of use to open space. The literature review has shown that Sydney currently meets its opens space targets in 2019. However, once you look closer at the open space provisions within Haymarket it shows a different scenario. When you look at the amount of space per suburb in the CBD – Haymarket/Chinatown have the lowest amount of the open space provision and as a

suburb it is lacking. The figure below demonstrates that Haymarket/Chinatown is the lowest scoring in the open space allocated.

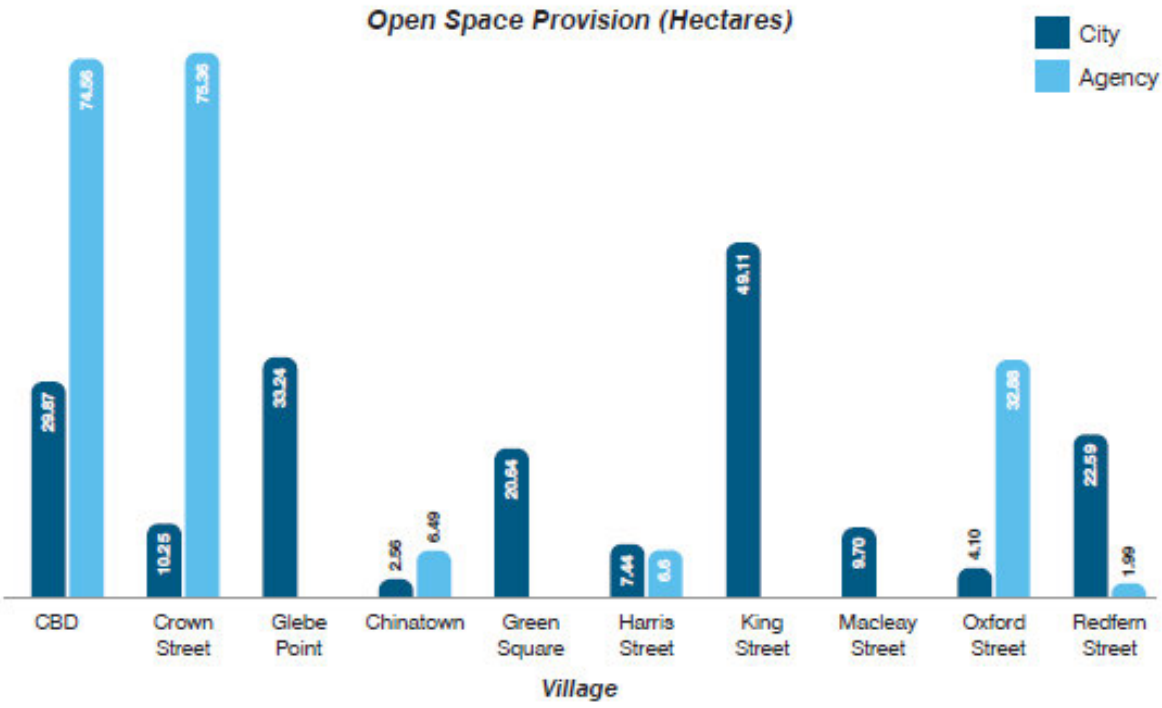


Figure 1.12: Sydney CBD Open Space Provision (City of Sydney 2016)

The land use survey backs up this data. In Haymarket the land use survey identified that the City of Sydney provides open space in the form of a public park at Belmore Park. This park is bounded by Eddy Avenue, Pitt Street, Hay Street and the railway line, Haymarket, in front of Central Railway Station. The area features extensive grass areas, wide shaded tree-lined paths and ample seating and public toilets. The size of the park is 11 032 m².

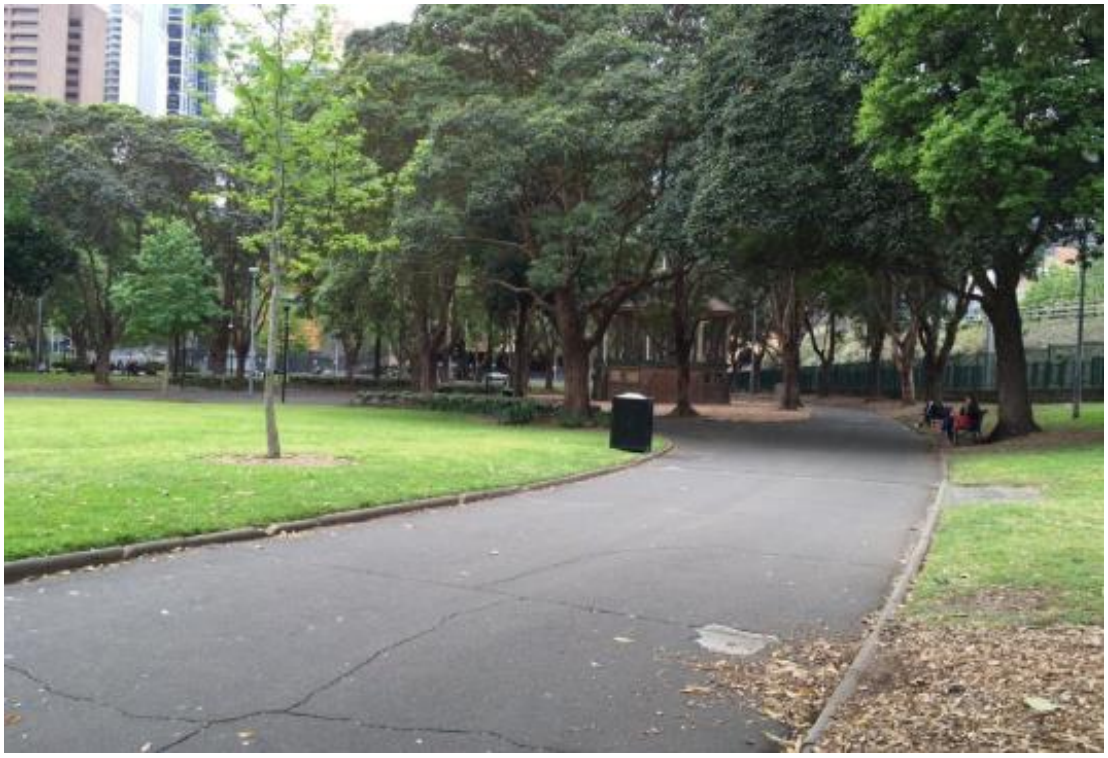


Figure 1.13: View of Belmore Park – Haymarket (Google Street View, 2019)

Figure 1.14: Aerial View of Belmore Park - Haymarket (Google Maps, 2019)

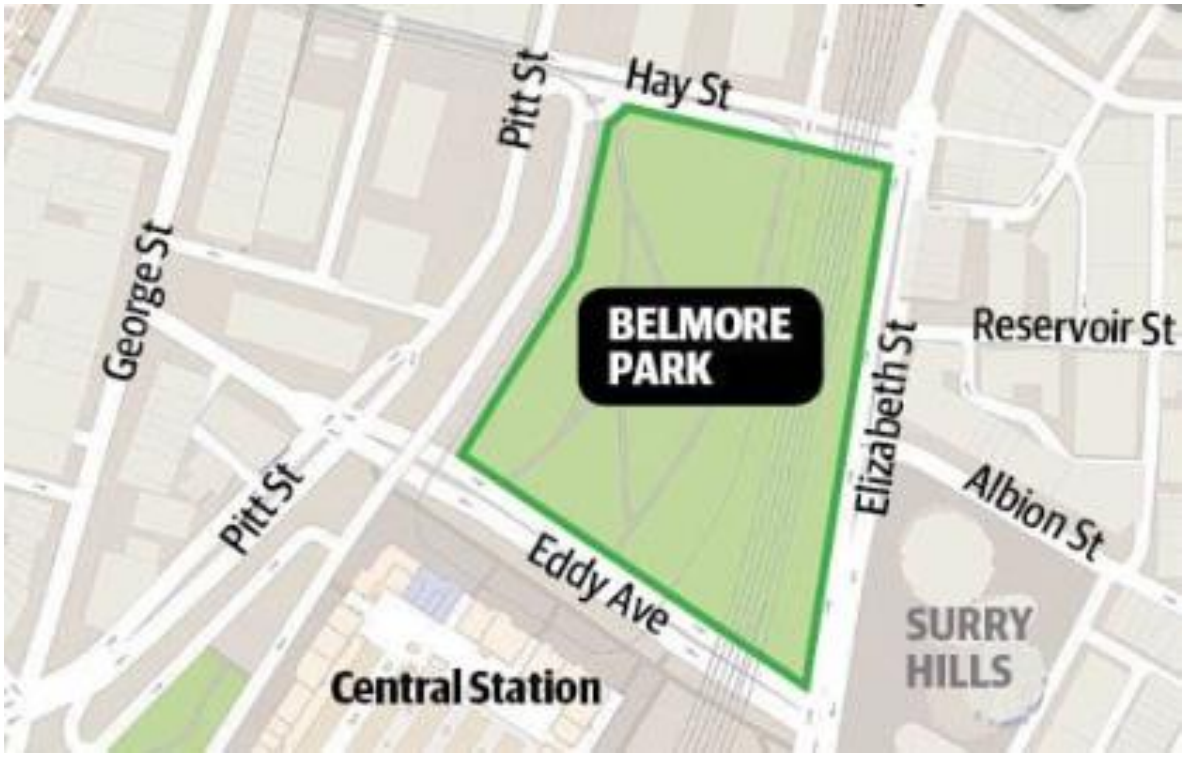


Figure 1.15: Location of Belmore Park (Profile.id, 2019)

As it can be seen below in the figure Haymarket/Chinatown have the smallest allocation open green space of all the CBD of Sydney. This is reinforced by the results of the land use survey which observed only one park in the suburb.

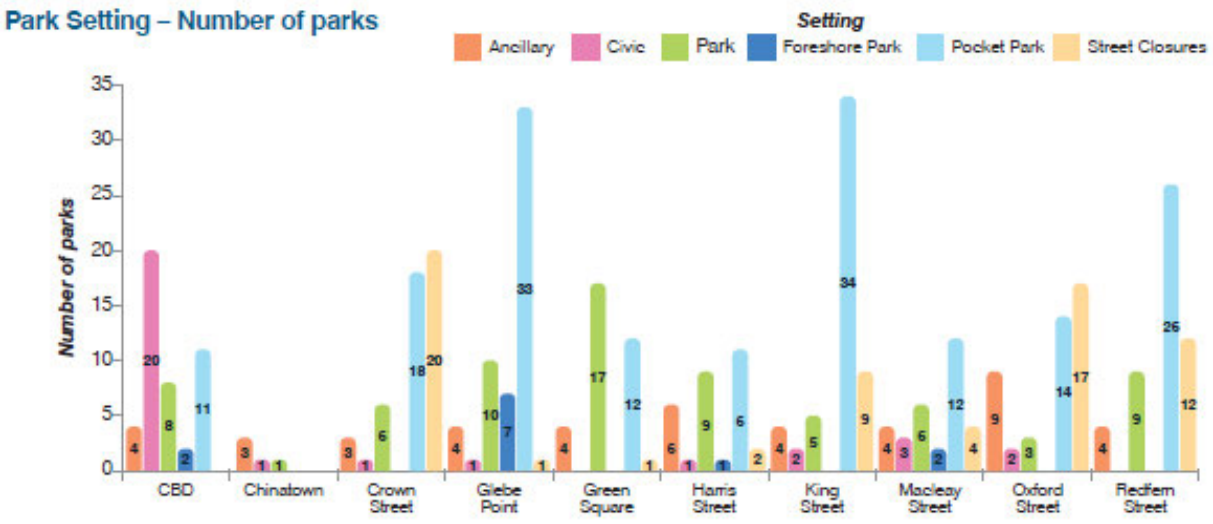


Figure 1.16: Number of Parks by Suburb (City of Sydney 2016)

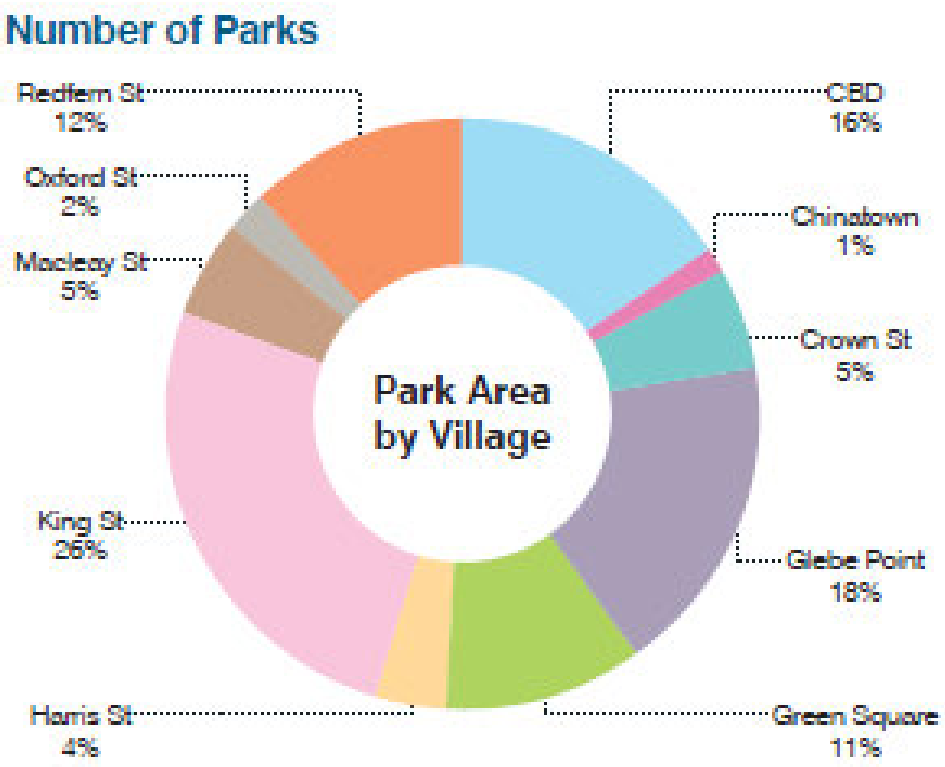


Figure 1.17: Percentage of Open Space per Suburb in CBD (City of Sydney 2016)

This figure above shows that the amount of open space in each suburb bears little relationship to the population in that suburb. Haymarket/Chinatown has highest population density and but also has the second lowest amount of open space per 1,000 persons. Most research recommends a good provision of public open space in high density areas due to less private open space, and to contribute to the social and health benefits and livability of a neighborhood. However, this is where Haymarket falls short of the open space provisions.

4.4.2 New Open Space Provision - Haymarket

There are future challenges facing Haymarket beyond open space area provision such as population/density and demographic profile, open space distribution, barriers, size, connectivity, and quality of visitor experience. When considering these factors more open space will be required and the challenge is how to increase open space provision with a finite land supply that has many competing use demands. The proposal of turning the land used for on-street parking which is projected to be made redundant due to the adoption of level 5 AV's to open green space is a valuable solution to Haymarket's lack of open space. If the amount of land (27097.200 m²) were to be repurposed to open space in this suburb would triple the open space provision for Haymarket.

4.5 STAGE TWO – TRANSECT

Stage Two of the dissertation presents the qualitative data in the form of a transect. A transect line is taken through the study area to visualise how Haymarket would look if the area of land currently used for on-street parking were converted to open/green space in an attempt to determine is this is a viable scenario by examining what is the likely impact of this change of land use in a CBD. The transect will be used to examine the impact the land use change will have on urban form and structure. The Transect from best practise the NGP Guidelines will be used as a tool to visually analyse any changes to urban form and structure.

The map below shows where the line of the transect has been taken through the study area. The line has been located to demonstrate a typical view of Haymarket by cutting through a variety of land use. The transect line extends from inside the boundary of Haymarket at Darling Drive across several streets (with and without on-street parking) to the other side of the suburb at the boundary of Haymarket at Elizabeth Street. The line of transect is shown in the figure below.

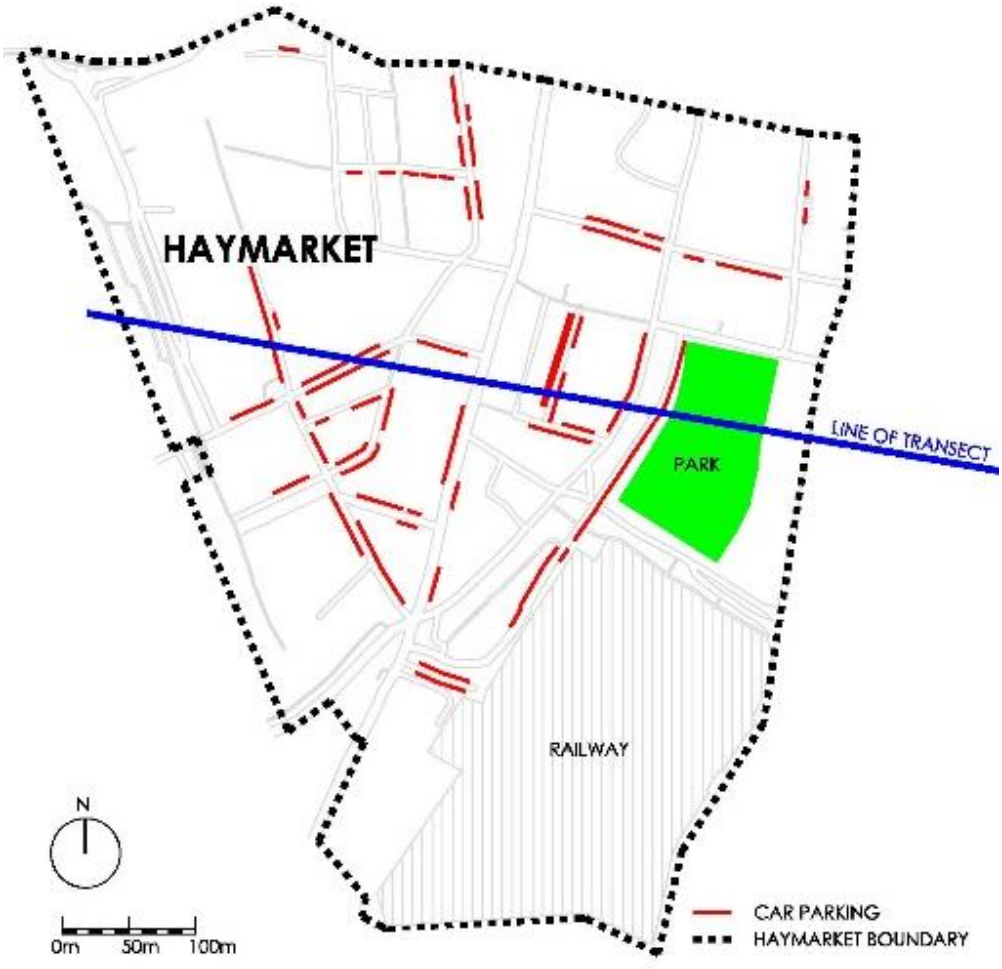


Figure 1.18: Line of Transect Plan (Author 2019)

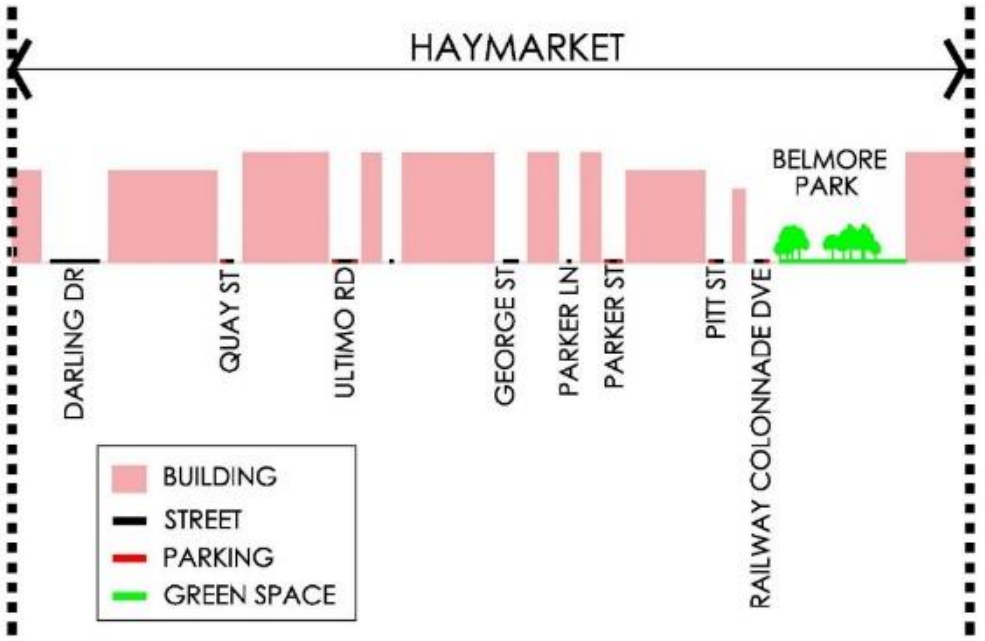


Figure 1.19: Existing Land Use on Line of Transect (Author 2019)

The figure above depicts the transect as it cuts through the suburb in section. The transect identifies the land use for the focus of this dissertation such as built zones, areas for streets and on-street parking along with open/green space along the line. The proposal of this dissertation is to change the land currently used for on-street parking be repurposed to open green space. To examine this change an alternative transect along the same line has been developed below.

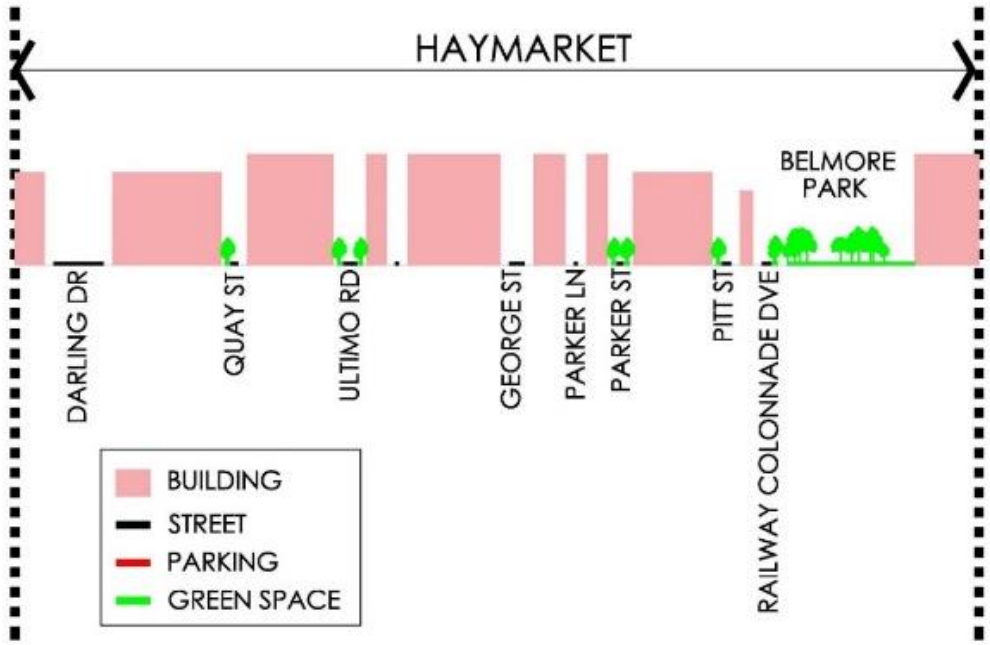


Figure 1.20: Proposed Land Use Transect (Author 2019)

The proposal is to turn the area of redundant on-street parking to open/green space. The figure below shows how Haymarket would look in plan/aerial view under this scenario with the area of on-street parking from the land use survey re-purposed as open/green space. It shows the location, size and distribution of how this would look in Haymarket if they were open/green space. These results will be used in the next section to determine the potential impact on urban form that would result from a change in land use from parking to open space would have in the study area.

Figure 1.21: Proposed Plan of Haymarket (Author 2019)

4.6 POTENTIAL IMPACTS TO URBAN FORM

This section of the dissertation will assess the transect against a best practice urban design planning tool to determine the changes to urban form and structure are in line with the principles it outlines for a CBD.

The literature review presented the NGP Guidelines as an example of a best practice tool to be used to examine urban form and structure of CBDs. Haymarket is classified by the NGP Guidelines as being representative of the P7 Zone – CBD. The characteristic elements for this classification are listed in the following table.

Table 1.4: NGP Characteristic Elements for Zone P7 CBD

Zone: P7 – CBD

P7 – CBD Characteristic Elements:

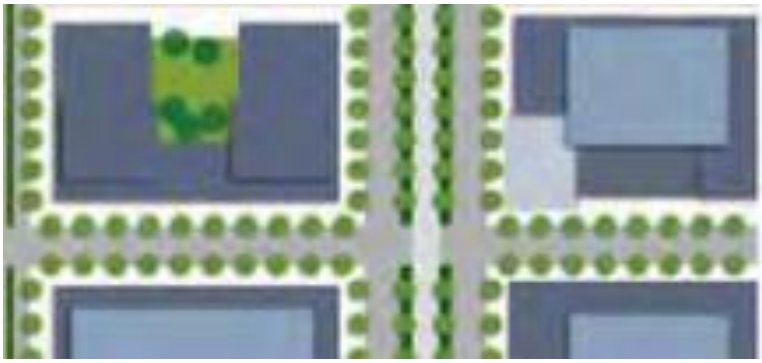
1. Centre of the city.
2. Biggest centre.
3. Widest range and greatest intensity of activity in the city.
4. Heart of a city.
5. Laid out in a grid.
6. Centre of transport networks, for public transport, cycling and pedestrians.
7 Is an urban environment.
8 Buildings dominate the streets, but streets are still important elements.
9 Large scale and intensity provides a vibrancy unlike any other part of the city
10 Key focal point for their communities, as places to work, do business, for entertainment or just to enjoy.
11 They are meeting places, with squares and urban parks.
12 Important to the economy of the city, both as centres of production and consumption.

13	Streets are lined with street trees, have hard footpaths for walking trips, and roadways shared use by cars and bikes.

P7 – CBD Typography in Section

(Council of Mayors (SEQ) 2011)

P7 – CBD Typography in Plan



(Council of Mayors (SEQ) 2011)

The transect generated through the study area is assessed against the elements identified above to determine the impact of changing the land use from on-street parking over to open space on the built form and structure to determine - does the land use change still fit the typology described for this zone? The aim is to identify if the change is viable or it will substantially alter that habitat characteristics that must be present for that zone to classified P7 CBD.

4.6.1 Assessment of Characteristic Elements for Zone P7 CBD

Haymarket is assessed below as to whether the proposed change in use from on-street parking to open/green space impacts any of the characteristic elements taken from the Next Generation Planning Guidelines as being representative of the P7 Zone – CBD.

1. Centre of city.

Impacted: No

The city centre is still identifiable as the centre as no factors that determine a city centre have been impacted such as buildings, transport, population, commercial activity and tourism.

2. Biggest centre.

   Impacted: No

   Haymarket remains a part of the CBD which is the biggest centre in Sydney. There are no changes to this.

3. Widest range and greatest intensity of activity in the city.

   Impacted: No

   The range and intensity of activity in the city is not affected by this change. Land use that determines range and activity have not been altered – for example commercial land use remains unaffected.

4. Heart of a city.

   Impacted: No

   Haymarket remains geographically in the heart of the CDB as demographics, retail, night life, transport links and leisure activities that are at the heart of a city have not been impacted.

5. Laid out in a grid.

   Impacted: No

   The layout of Haymarket is still in a grid pattern or remains as it was. No directions of streets have been changed.

6. Centre of transport networks, for public transport, cycling and pedestrians.

   Impacted: Yes

   The transport networks have been impacted. There are changes to how pedestrians and cyclists behaviour in Haymarket resulting from the change in land use. However, the transport networks for public transport or not affected.

7. Is an urban environment

   Impacted: No

   Haymarket remains an urban environment.

8. Buildings dominate the streets, but streets are still important elements

   Impacted: Yes

   Buildings remain unchanged and continue to dominate the street and the streets are still important elements however the way people view and use the streets has been changed. The streets are no longer exclusively for the use of cars.

9. Large scale and intensity provides a vibrancy unlike any other part of the city

   Impacted: No

The large scale of Haymarket has not been affected as there have been no changes to the

factors that determine if an area is intense and vibrant such as retail, commercial, tourism, population density and transport access.

10. Key focal point for their communities, as places to work, do business, for entertainment or just to enjoy

    Impacted: Yes

    This element has been impacted as the change in land use is expected to provide additional focal points for the community to enjoy.

11. They are meeting places, with squares and urban parks

    Impacted: Yes

    The change in land use will impact meeting places, squares and urban parks as it is expected to add to the opportunity to access these places by providing more of them.

12. Important to the economy of the city, both as centres of production and consumption streets are lined with street trees, have hard footpaths for walking trips, and roadways shared use by cars and bikes.

    Impacted: Yes

    The economy of the city as the centre of production and consumption will not be impacted. However, the streets lined with trees, having hard footpaths for walking trips, and roadways for shared use by cars and bikes will be impacted. The change in use is expected to add to the streets lined with trees and will alter how pedestrians use footpaths and how roadways are used by cars and bikes.

The assessment of Haymarket against the characteristic elements in the Next Generation Planning Guidelines as being representative of the P7 Zone – CBD has identified some impacts to the elements that must be present for that zone. The potential impacts to the urban form are moderate. Even though there are impacts it can be demonstrated these are a positive contribution to Haymarket for now and in the future. Based upon the literature review which presented the key themes from visions for Sydney outlined in policy documents, it can be shown that the changes to the urban form and structure are in line with the scenarios the policies present. The potential impacts contribute to the CBD positively by providing a much

more liveable urban environment, connectivity and a linear network of parks that didn't exist before given the scarcity of available land.

4.7 LIVEABLE URBAN ENVIRONMENTS

The literature review identified several elements that should be present in liveable urban environments. These elements have been summarised and will used to demonstrate that although the change in land use has moderately impacted the urban form and structure of Haymarket – the potential impacts are positive due to being in line with visions proposed for Sydney and the notion of a liveable urban environment. The key themes such as connectivity and green linkages (in the form the Livable Green Network) identified in the policy documents for the future of Sydney are used to assess the suitability of the change in land use that is proposed.

Table 1.5: Sydney Policies for Liveable Urban Environments

1. The Open Space, Sports and Recreation Needs Study 2016 by The City of Sydney.	
Key Themes	Increased density - allow for more people to live in Sydney and in increasing densities (City of Sydney 2016).
	Healthy living – promotion of health and fitness to reduce rates of obesity and chronic disease in the community, provide mental health benefits and foster individual and community well-being (City of Sydney 2016).
Comment: Haymarket is predicted to have the highest population growth of all the Sydney CBD in the future and as a result more people in line with this policies vision will be living in a dense environment. Given that they will have no real 'backyard' due to dense living the provision of an additional 27097m² of land to be made available for open space will impact positively on the residents. The additional provision of open space will enable them to experience and participate in healthy living as outline by this vision for a liveable urban environment. This additional open space area provision in high density areas is essential to compensate the lack of private open space, support active living, and to contribute to a more livable neighbourhood. The result is a positive impact to urban form.	
2. Greener Places: Establishing an urban Green Infrastructure policy for New South Wales by Government Architect.	
Key Themes	Create a healthier, more liveable and sustainable urban environment by improving community access to recreation and exercise, supporting walking and cycling connections, and improving the resilience of urban areas (GANSW 2019).

<table>
<tr><td colspan="2">Comment: The change in use of on-street parking to open green space will create a myriad of linear parks which will provide opportunity for additional connections to existing walking and cycling paths of the city which is in line with this vision. The geographic distribution of public open space is a key access and equity issue for the community. The ability of residents to gain access to public open space within an easy walk from home is an important factor to quality of life. The result is a positive impact to urban form.</td></tr>
<tr><td colspan="2">3. Greening Sydney Plan by City of Sydney by the City of Sydney.</td></tr>
<tr><td>Key Themes</td><td>Expanding the urban forest (City of Sydney 2012).</td></tr>
<tr><td></td><td>Creating greener streets (City of Sydney 2012).</td></tr>
<tr><td></td><td>Providing more parks and open space (City of Sydney 2012).</td></tr>
<tr><td></td><td>Greening new development and private land (City of Sydney 2012).</td></tr>
<tr><td colspan="2">Comment: The change in land use from on-street parking to open green space will provide additional land and opportunity for the planting of trees to contribute to expanding the urban forest and create greener streets. The provision of an additional 27097m² of land for more parks and open space is in keeping with this documents vision. The result is a positive impact to urban form.</td></tr>
<tr><td colspan="2">4. Sustainable Sydney 2030 - Community Strategic Plan 2017– 2021 by The City of Sydney.</td></tr>
<tr><td>Key Themes</td><td>Outlines a plan for a green, global and connected city (City of Sydney 2009).

Green with a modest environmental impact, green with trees, parks, gardens and linked open spaces, green by example and green by reputation (City of Sydney 2009).

Global in economic orientation, global in links, partnerships and knowledge exchange, global and open-minded in outlook and attitude (City of Sydney 2009).

Connected - easy to get around with a local network for walking and cycling, and transit routes connecting the city’s villages, city centre and the rest of inner Sydney (City of Sydney 2009).</td></tr>
<tr><td colspan="2">Comment: The provision of an additional 27097m² of land will provide opportunity for trees, parks and linked open spaces which will contribute and connect to the local network for walking and cycling which is a key outcome of this vision. The result is a positive impact to urban form.</td></tr>
</table>

4.7.1 Connectivity

The degree to which open space is linked is a crucial dimension of future planning for improved park use in the city and access to a diversity of recreational experiences. While proximity is a key driver of use, where proximity is poor then actual access through adjoining streets and

linkages becomes crucial, especially for those people without cars or in areas of poor public transport.

The promotion of open space networks across the City provide greater opportunity for recreation, promote physical activity, enhance access to other parks and community facilities, improve visual amenity and create wildlife corridors. Key to creating open space linkages is to connect to Sydney City's Liveable Green Network and at a wider regional level the State Governments Sydney Green Grid project.

4.7.2 Green Linkages

The concept of green linkages in Sydney is illustrated in its Livable Green Network. The network proposes new cycleways and pedestrian links across the city and makes walking and cycling a viable option to access the open space and recreation network. The area of land repurposed to open space can contribute to the liveable environment as they provide pockets of green space that will provide spaces for the community that promotes physical exercise by providing small spaces for cricket, handball or half court tennis. They can promote mental health as the environmental corridors and connection with nature provide an escape from urban environment. They also allow people to enjoy recreational and sporting activities and therefore foster social connectedness. Children can safely explore the natural environment and develop physical and social abilities and additionally they celebrate a city's sense of place, culture and heritage.

4.8 RECOMMENDATIONS

Based on the assessment of the transect which demonstrated the change in use from on-street parking to open space it can be concluded that there were moderate impacts to urban form. The assessment was completed using the NGP guidelines to make this determination. The concept of turning the amount of land to open space was then analysed against key themes presented by policies for Sydney urban environment to demonstrate that even though there were moderate impacts they were however positive and in keeping with the visions put forward to guide Sydney's urban environment for the future.

Through this analysis and the way in which the data was gathered and related back to the literature, the findings of this dissertation have demonstrated that a change in land use will result in a more connected and liveable urban environment. Based on the knowledge gained it can be recommended that this dissertation has shown the proposed change in land use is a

viable solution to population pressures facing inner city environment and their lack of open space.

4.9 CONCLUSION

This chapter has presented the results from Stage One of the data collection - being the land use survey. The results are followed by a discussion to answer the research question of what are the potential impacts of AVs on land use (on-street parking) in Sydney.

The next part of the chapter presents the results and discussion of Stage Two of the data collection which was a transect. The transect is assessed against the best practise urban design planning tool to determine the impact on urban form and structure. The desirability of the impacts are discussed and analysed using the visions outlined for the future direction of Sydney's urban environment in policy documents. Stage Two has answered the research question of what would Sydney look like if the land available from redundant parking were repurposed as open space?

The next chapter will provide a conclusion of the discussion. This will detail a summary, reiterating the aims of the dissertation and how they were achieved through the results and analysis. It will also recommend future studies and provide final remarks.

Chapter 5: Conclusions

5.1 SUMMARY

The aim of this dissertation is to examine the potential impacts of autonomous vehicles on urban form and land use in Sydney. In particular it looked how level 5 adoption of AVs will impact on-street parking in an urban environment, by conceptualising the repurposing of redundant land to open space using Sydney as a case study.

This was firstly investigated by reviewing the literature on AVs in order to define what they are, their timeframes for adoption and their impacts on the built environment and on-street parking. The next part of the review was to look at urban environments, what makes a city by looking at urban form and structure and what constitutes quality open space in these urban environments.

This was followed up by conceptualising how would the city look if the land used for parking were made redundant in the future (as level 5 AV adoption projects) and was to be repurposed as open space by reviewing the literature on best practice for open space in urban environments and the process of visioning for urban design.

The literature review informed the next section of the dissertation which outlined the methodology to be used, the data collection method and validation, equipment and software to be used and that a pilot study was conducted to demonstrated that dissertation was robust in its design.

Following on from the methodology chapter the results and discussion are presented together. The results from Stage One of the data collection are presented and discussed first. This is followed by the results and discussion for Stage Two of the data collection.

This chapter will detail a conclusion of the dissertation including a summary of the findings linking them back to the objectives; as well as recommendations for future research; and then final remarks will be presented.

The objectives of the dissertation were to investigate the potential impact of AVs on land use (in particular, on-street parking), the potential impact redundant parking would have on a city, how would the city look if the land made available were repurposed for open space.

The objective of examining potential impact of AVs on land use (in particular, on-street parking), has been achieved in the literature review which outlined that level 5 adoption of AV would make on-street parking redundant. The objective of the exploring the potential impact

redundant parking would have on a city has been achieved through hypothesising how would a city look if this amount of land remaining from redundant parking was repurposed into open space. This has been achieved by presenting best practice examples for open space, greening and outlining the visioning policies for open space and applying the principles to the change in land use to imagine how the scenario would look for Sydney. The scenario is then assessed for its impact on built form and structure by using a best practice urban design tool and its ability to meet the visions outlined in policies for Sydney.

5.2 FUTURE RESEARCH

Further research is needed to better understand the impacts of AVs in different geographic contexts and could examine the potential impact of AVs on urban form and land use in rural and suburban areas. Most work to date has addressed the implications of AVs in urban environments. For example, rural areas lack the population density for which many predicted benefits are projected from. Consequently, these areas may be affected by the secondary impacts of AVs such as sprawl and will exacerbate the rural urban divide.

Given the collection of current research covers the effect of AVs and their potential advantages, future work could concentrate on the timeframe and transition period towards the total adoption of AVs. The research could explore how the dynamics of AV vehicles with traditional vehicles will look and behave during the transition period and what impact does that have on land use.

Additional work could look at impacts of AV on other areas of the built environment such as streets. Research indicates that governments, local councils and legislative bodies will need to develop new street standards to facilitate multiple forms of travel in the future. They will need to address items such as integrating complete streets with safe vehicular traffic, pedestrians, cyclists, and transit facilities.

New street typologies and typical cross-sections for different types of streets such as narrower lane widths and ample sidewalks, bicycle lanes and drop off zones. Guidance will need to be incorporated for the location and design of drop off zones on the streets. For example: vehicular drop-off and pickoff may be prohibited along some street frontages in order to maintain other modes and uses.

New specifications will be needed to cover the removal of traditional traffic infrastructure such as signage and signalisation whilst incorporating subtle vehicle-to-infrastructure networks within the public right-of-way and providing navigation/wayfinding systems and other facilities that distinguish and prioritize pedestrian and cycle movement.

5.3 FINAL REMARKS

The literature investigated for this dissertation has highlighted the necessity to begin planning now for the arrival of AVs by examining their potential impacts on land use and therefore urban form. It emphasized that the aim was to gain an understanding of how AVs will shape our urban environments in the future by using a real-world city in the Australian context. It examined the potential impacts AVs will bring to our cities by hypothesizing how would Sydney look if the area made available from redundant on-street parking were turned into open space. It concluded by assessing the suitability of the land use change.

Through the methodology employed, this dissertation has gained insight into what the potential impacts AVs at level 5 adoption would have on parking and how this impact will look by examining the scenario in Sydney by outlining the metrics and theory for repurposing the land used for parking to open space.

Overall this dissertation has proven that the land made available from the full adoption of AVs in our CBD is more than suitable to be repurposed as open space and the impacts to urban form from the land use change are in a positive direction and in line with the visions for a sustainable Sydney outlined in current polices.

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Appendices

Appendix A

Project Specification

ENG4111/4112 Research Project
Project Specification

For: Kim Jolley

Title: The Potential Impact of Autonomous Vehicles on Urban Form and Land Use in Sydney (CBD) – A Case Study

Major: Spatial Science (Surveying)

Supervisors: Dr Marita Basson and Jessica Smith

Enrolment: ENG4111 – EXT S1, 2019
ENG4112 – EXT S2, 2019

Project Aim: To Investigate the Impact of Autonomous Vehicles on the Urban Form.

Programme: Version 1, 20th March 2019

1. Research and review the literature on autonomous vehicles and their impact on urban form from a North American perspective and from an Australian perspective.

2. Use the literature review to inform the:
   → selection of the geographic area for a case study (suburban sprawl)
   → scale/timeframe of autonomous vehicle adaptation
   → conceptual framework to use for assessment of the impact to the urban form

3. Apply the framework to the case study for the data collection.

4. Analyse and interpret the results.

5. Submit an academic dissertation on the research.

As time permits:

6. Draft a conceptual design of the urban form with the framework as applied to the case study.

Appendix B

Trundle Specifications

Craftright Lightweight Measuring Wheel

Product details

Model Name	Measuring Wheel	**Material**	Nylon, aluminium alloy and rubber
Product Dimensions (mm)	W:160 H:135 L:920	**Collapsible**	No
Kick Stand	No	**Lockable**	No
Digital Display	No		

Product description

Measure long distances quickly and easily using Craftright's Lightweight Measuring Wheel.

Complete with an extendible handle, easy to reset counter and a carry bag for portability this measuring wheel is ideal for estimating paving jobs, lawn areas, carpeting areas and much more!

For extra stability when measuring, the Craftright Lightweight Measuring Wheel has been designed with two wheels instead of one, giving you greater accuracy.

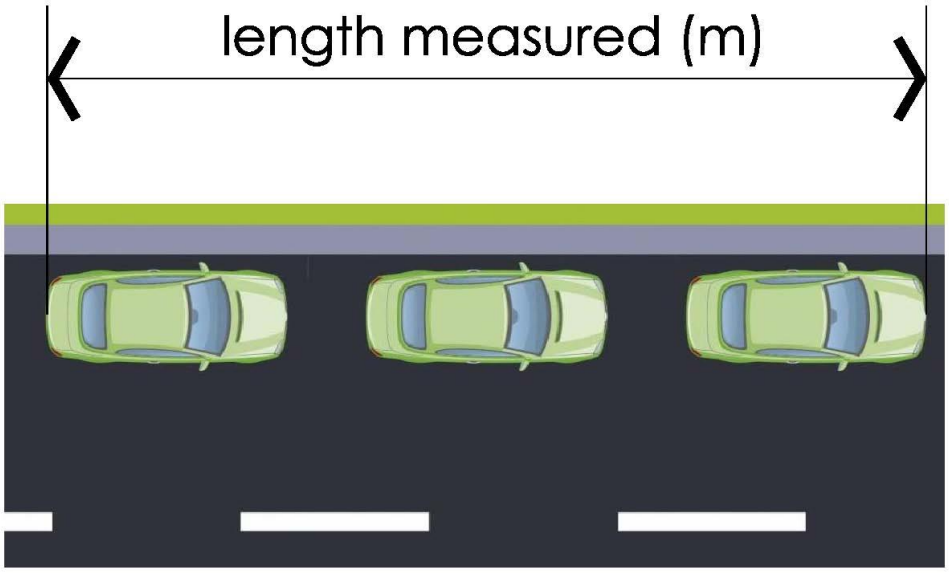
- Extendible handle
- Lightweight and compact
- Carry bag for storage and portability
- Durable
- Twin wheels for extra stability

Appendix C

Measurement of On-Street Parking Length

Method of measurement for on-street parking undertaken in the land use survey.

Street length = distance between the signs at the start and end of parking zone on street.



Appendix D

Measurement of On-Street Parking Area

Note: Area is calculated using Standard Car Park Dimensions as per Section 4 - City of Sydney DCP as 2.6m x 5.4m = 14.04m²

4.2.1 Length of Parking Spaces

All bays shall be a minimum 5.4m long with the exception of:

- Spaces with an overhang into adjacent landscaped areas may be reduced to 4.8m;
- Small car spaces which can be reduced to 5.0m (refer to Section 4.3);
- Parallel spaces which are required to be 6.0m normally, or 6.3m in an end space.

4.2.2 Width of Parking Spaces

The minimum width of car parking spaces for the various categories of users is set out in the table below. The widths are based on considerations of door opening requirements and frequency of use.

Use category	Examples of typical users	Space width
Low turnover	All day and commuter parking	2.4m
Medium turnover	Duration of stay between 2 hours and all day, eg; tenant parking in residential buildings, sports facilities, hotel parking	2.5m
High Turnover	Short term parking, visitor parking, parking where children and goods are frequently loaded, eg; shopping centres	2.6m
Disabled user	Parking spaces reserved for use by the disabled	3.2m
Small Car Space	Refer Section 4.2.3	2.3m
Parallel Parking	Normal conditions	2.3m
	Restricted roadway width	2.1m
	Trucks and buses	2.6m