BICYCLE REVOLUTION

A New Bicycle Network for Auckland: Towards an elevated cycleway development in Auckland CBD.

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ABSTRACT

A correlation between the increasing use of fossil fuels and decreasing quality of urban environments is now generally conceded. The biggest culprits of urban pollution are combustion-driven vehicles. As a result, interest is growing in viable ‘green’ alternatives to city mobility. A top consideration is the common bicycle, which has been regaining popularity in compact cities as a simple, inexpensive, low-impact and localised solution to moving within cities. A broad scale adoption of bicycling as a primary mode of travel still faces critical issues of infrastructure, convenience and ease. In the case of Auckland, however, a strong outdoor culture rarely includes cycling in the many definable ‘kiwi’ outdoor activities. Reasons given for this include the problems of geography (Laing, 2014; NZ Transport Agency, 2011), climate (NZ Transport Agency, 2011), and infrastructure (Matt, 2014). Nevertheless, Auckland Council has acknowledged the successes of other cities, such as Copenhagen, New York and London (NZ Transport Agency, 2011), and has promised investment of $300m over the next 10 years (Auckland Transport, 2015). Despite the resolve to extend the cycle network, the Auckland Council’s proposal has not yet resolved conflicts between the distinct user groups of large road-vehicles (cars, etc.), small road-vehicles (bikes, etc.) and pedestrians. As a result, the current programmes deal inadequately with safety, aesthetics and expense. This project suggests a separation of existing networks, and explores the opportunities of designing an independent cycle network that would provide excellent synergy with existing infrastructure while clearly separating use – for the safety and benefit of cyclists, motorists, and pedestrians. It is expected that such a cycle network would encourage cycle use as a primary form of transportation, making Auckland a greener, safer, more enjoyable and less expensive place to live.
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1.0 INTRODUCTION

Project scope
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1.1 PROJECT SCOPE

A worldwide issue

A correlation between increasing use of fossil fuels and decreasing quality of urban environments is now generally conceded. Many of the environmental issues the world faces today, including global warming, air pollution, acid rain and oil spills, result from our fossil fuel dependency (Myhre et al., 2013; Environmental Protection Agency, 2016; International Tanker Owners Pollution Federation, 2013). Over the past two decades, the burning of fossil fuels has resulted in about 75% of human-caused emissions (U.S. Department of Energy, 2015). Combustion-driven vehicles are a significant contributor to urban pollution, creating over 20% of the global carbon dioxide emissions (Burns, 2013; Harrington & McConnell, 2003). In 2014, the energy sector contributed 39.7% of New Zealand’s CO2-equivalent (CO2-e) emissions, and road transport represented 43.8% of these. A striking feature of transport emissions has been their rapid growth, with road transport emissions increasing by 60.7% between 1990 and 2014. At this level, road transport has been a major contributor to New Zealand’s overall rate of emissions increase: 38.6% over the 24-year period (Ministry for the Environment, 2015).

As a result, interest is growing in viable ‘green’ alternatives to city mobility. Over the past 20 years, various technological choices were under discussion in literature and policy-making (van Wee, Maat, & de Bont, 2012). A strong push to commercialise electric vehicles (EVs) began with California’s Zero Emission Vehicle (ZEV) programme in the 1990s (Graham, Cisney, Carley, & Rupp, 2014). Californian electric automaker Tesla Motors began development in 2004, and had sold at least 2250 Roadsters in more than 31 countries by 2012. Until now, the world’s top-selling highway-capable electric car, the Nissan Leaf, has sold over 180,000 units in 46 countries (“Electric car”, 2015). Compared with EVs, cars with hybrid engines need less time to recharge, but have fewer charging stations. Compared with gasoline cars, the conventional hybrid costs more to produce, but has 30% fuel economy and fewer maintenance and repair costs (Graham, Cisney, Carley, & Rupp, 2014). As another main mode of ‘green’ alternative mobility, e-bikes, with their relatively low price and extra use for recreation are now sold on a vast scale in the worldwide market. However, e-bikes don’t give the rider much exercise, and can easily exceed speed limits. The development and acceptance of e-bikes remains uncertain (Lesser, 2012).

In addition, the top consideration of ‘green’ alternatives to urban mobility is the standard bicycle, which has been regaining popularity in compact cities as a simple, inexpensive, low-impact and localised solution to moving within cities. Results of international studies show that the primary concern of shoppers is cycling and walking, and car access is less important to the local economy (Auckland Council, 2014). As a more convenient and affordable transport option, bicycles bring not only health benefits to individuals, but also benefits to society, such as more efficient land use and street design, the decreasing of congestion and increasing access to jobs and services.
Present solutions in modern cities

Copenhagen.

A bicycle culture has been developed step by step over the last 50 years in Copenhagen. They now have 350kms of bike lanes in the city. People can easily travel through the city without a car. Bicycling rates have doubled over 10 years; now 37% of people commute to work every day by bike, and 12 million kilometres are covered by cyclists daily (Ministry of Foreign Affairs of Denmark, n.d.).

New York.

New York was a city without a bicycle culture, the whole city was filled with car traffic, and people thought they didn't have time to ride bicycles. However, on February 26, 2009, Mayor Michael Bloomberg announced that closing traffic lanes along Broadway from 42nd Street to 47th Street and 33rd to 35th Street and transforming into pedestrian plazas (Seifman, 2009) and putting seats in the Times squares, people began to fill this place. In only six months, the government took traffic out of Broadway, people began to enjoy walking and bicycling, and enjoying their public life in New York. In 2012, the city of New York was awarded the world city prize (Urban Redevelopment Authority, 2012).

Melbourne.

In the 1980s, central Melbourne with poor planning strategies faced with the migration out of the central area of important central city activities, such as retailing, made Melbourne a city with ‘doughnut syndrome’- a city without a strong central core (Adams, 2006). During the city’s regeneration in the 1990s, it was discovered that the narrow and shady laneways were an ideal human scale and pedestrian connections (Drawn to Cities, 2015). In 1994, Danish architect and urban designer, Jan Gehl, reported that laneway revitalization would impact the way people use the city and found out opportunities for Melbourne laneway’s ongoing improvement (Drawn to Cities, 2015). What used to be the creepiest places in the city center have been made attractive by The City of Melbourne. Pedestrian traffic in the city centre has increased by 40% in daytime and has doubled in the evening (Drawn to Cities, 2015). Melbourne city has successfully been transformed.

Local issues & challenges

Auckland is a car-dominated city which experiences traffic congestion everyday. Auckland’s transport system currently accommodates 4.2 million passenger trips each day, with modal shares of 74% private vehicle, 5.6% active modes (walking and cycling) and 7.4% public transport (buses and trains) (Pauling, 2014). The statistics show that commuters in the Auckland region spent 45 minutes per day on average, or more than a week per year, stuck in traffic last year, which means drivers are spending 38% extra time on roads because of traffic congestion (TomTom Traffic Index, 2016). Only 1.2% of all trips to work are made by bike (Auckland Council, 2014). A
widescale adoption of cycling as a primary mode of travel still faces critical issues of infrastructure, convenience and ease. In the case of Auckland, though revitalisation of cycling is promoted by political and infrastructure initiatives, we can easily see on a map that the existing bicycle network is incomplete. Currently, in Auckland, cycling trips comprise only 0.6% of all trips on weekdays (Auckland Council, 2014). Auckland has a much smaller population and much smaller population density than the cities mentioned above. If we want to encourage cycling, we need to find a way that will be attractive to Aucklanders, to change our culture step by step; otherwise, we are just wasting money on bike lanes or cycle highways that few people will use.

From these research, the five main factors appear to be (1) a well-connected network of cycleways; (2) safety; (3) convenience; (4) a good public transportation system integrated with cycling facilities; (5) policies to discourage car use.

Moreover, Auckland Council has promised an investment of $300m over the next 10 years (Auckland Transport, 2015). In the Auckland Plan of early 2014, 70% of the cycle network was to be completed by 2020, however council estimates that only 40-50% will be completed with the current funding (Auckland Council, 2014). Despite the resolve to extend the cycle network, the Auckland Council proposal has not yet resolved conflicts between the distinct user groups of large road-vehicles (cars, etc.), small road-vehicles (bikes, etc.) and pedestrians. As a result, the current programmes deal inadequately with safety, aesthetics, and expense.

**Local opportunities**

Cycling still has opportunities in Auckland. The Auckland Regional Transport Authority expected to achieve 15.5% of trips by walking and cycling through improving the walking network in the Auckland CBD and 17 other town centres, and completing 50% of the regional cycle network in 2016 (Auckland Regional Transport Authority, 2007). Witten, Huakau and Mavoa (2011) argued that trips for recreational purposes, the destinations of which are open spaces and eating and drinking places, may be more amenable to reducing fuel use. As a local, regional or national park can be reached in 2.4 minutes by car from three out of four New Zealand neighbourhoods and there are more than 4219 parks comprising 16.6% of Auckland’s land area, people in Auckland have very good access to parks and reserves (Witten, et al., 2011; Auckland Council, 2015), which makes the successful promotion of cycling for leisure possible. Recently, Auckland Transport recommended an investment of $635m in cycling over the period 2018-2028 (Auckland Transport, 2017).
1.2 RESEARCH QUESTION

Can an independent cycle network make bicycle use a primary form of transportation, to provide sustainable mobility for Auckland?

1.3 PROJECT GOALS & OBJECTIVES

Goals:

This project aims to investigate how an independent bicycle network can provide excellent synergy with existing infrastructure with clearly delineated uses that support the safety and benefit of cyclists, motorists and pedestrians. This will involve the use of a case-study design for a specific area in Auckland. The case-study design identifies how a design solution could be applied to similar situations in other parts of Auckland, or perhaps to the other cities.

Objectives:

1. To evaluate and analyse the existing conditions and potential future of Auckland’s urban mobility.

2. To examine and evaluate previous theories of urban planning, together with related precedents, creating an independent cycle network model in Auckland to enhance the liveability of Auckland City.

3. To improve the bicycle travelling experience to encourage cycling for local residents, through creating a coherent bicycle network between green spaces and business areas along low-volume local roads.
1.4 METHODOLOGY

As a research-based design project, this work provided the opportunity to investigate the relationship between bicycle networks and sustainable urban mobility in Auckland. The methodology for the research was divided into three main stages of the design thinking approach, to keep the topics clear and concise.

1. Literature review and theoretical research

The first stage of the research was identifying current conditions and challenges of urban mobility and relevant theories, comparing the advantages and disadvantages of theories of urban planning which could serve as a basis for the project. Critical focus was given to Jan Gehl’s human-centred urbanism. In addition, representative approaches and precedents, and the strategies and principles of cycleway design were explored to increase the safety and applicability of the project.

2. Context analysis and GIS analysis

The context and landscape analysis illustrated the Auckland urban area’s social, ecological and economic environment; Auckland Council’s past, present and future cycle network plans; and helped in the selection of a suitable site for the project. On a different scale, experiential analysis, through walking, observing and mapping, helped us to get to know the relationship between local people and the bicycle networks.

3. Application

In the last stage, the application of cycleway design principles and Jan Gehl’s human-centred urbanism through creating a new form of independent cycle network will help Aucklanders to think afresh about urban mobility and accept cycling as a primary form of transport. The three stages are linked to formulate a way of working through the project.
Literature review and theoretical research

Firstly, a study of current trends and conditions in transport-oriented mobility systems and environmental sustainability challenges of urban mobility helps to evaluate and analyse the existing issues and potential opportunities of Auckland’s urban mobility. Secondly, the research, which focuses on viable ‘green’ alternatives to city mobility and representative precedents of modern cities that promote cycling, such as Copenhagen, Amsterdam and Xiamen, enhances the understanding of relationship between bicycle network and quality of life in modern cities. Then, examine and evaluate previous theories of urban planning—New urbanism, The compact city and Human-centred urbanism, through comparing strengths and weaknesses of each theory. Finally, the exploration of the strategies and principles of cycleway design, together with related precedents, will be applied to the project which will generate a speculative model that is response to urban mobility issue in Auckland.

Context analysis and GIS analysis

The context and landscape analysis provided the knowledge of social, economic and ecological environment in Auckland, which is the cornerstone of site selection. However, data collection and spatial criteria are the key factors to generating and identifying the possible sites. Geographic Information Systems (GIS) are one of the essential tools for location mapping, dynamic condition visualization, and decision-making. In this research, GIS application played an important role in providing technical support in analysing topography, functions and the layout of the city. Experiential analysis, which investigated the site on human-scale, can not only help designer to know the relationship between local people and the environment, but also check the accuracy of data from GIS database.

Application

Based on the design strategies and principles explored from literature review, and data collection and analysis, initial tests of the site will explore potential design opportunities and constraints, followed by an ambiguous design concept. The design speculation will lead to ambitious yet pragmatic design moves to provide safety, connectivity and accessibility to bicycle infrastructure in Auckland. The design development phase encompasses design experiments of four conceptual zones with critiques of strengths and weaknesses. The factors rationalized through design by research will be critical in shaping the final design proposal.
2.0 LITERATURE REVIEW

Sustainable mobility
‘Green’ alternatives
Popularity of bicycles in modern cities
Theories of city planning
Design strategies & principles
Case studies
Summary
2.1 SUSTAINABLE MOBILITY

*Trends and conditions in transport-oriented mobility systems*

“Mobility in its myriad forms is a critical element of the transportation process, but it is inextricably intertwined with the physical infrastructure needed to move around” (Keeling, 2015, p. 59; Macário (2011) states that among the many subsystems of the urban system, the urban mobility system is the one that strongly influences the evolutionary capacities of other subsystems of urban life and, consequently, makes the development of the main upper system possible. The layout of the city and its functions, and the mobility system that connects the different pieces, are tightly related.

In all cities, the issue of mobility is essential, because mobility allows the interaction of people and the trading of goods, which are the two defining elements of the reasons for the very existence of cities. According to Shaw and Hesse (2010), mobility demonstrates various opportunities, constraints and freedoms that shape modern society “over time and across space” (p. 305). There are also very diverse examples of mobility patterns, intensities and shapes. This means, aiming for sustainability needs a fundamental transformation of thinking, decision-making and acting. However, urban mobility systems have a particularity that makes their quality control difficult, for the results are controlled by different organisations interacting in an uncontrolled environment – the urban space.

The current situation of urban mobility systems indicates that the system is highly motorised, and moving away from sustainability. According to Macário (2011), with the development of information and communication technologies, our societies are transforming into network societies. Current and future societies would be possibly characterised by high individualisation, so that individuals would become the basic reference unit. As a result, different social groups and heterogeneous areas would coexist, and the use of urban spaces would probably change from unique and monofunctional options to redundant multifunctional ones. In conjunction with this, the availability of private motorised transport is rising almost everywhere (Macário, 2000). Moreover, the world’s population is increasingly city-based. By 2050, populations in urban areas are expected to increase from 3.5 billion to 6.3 billion, comprising 70% of the global population, and the total amount of urban kilometres travelled is expected to triple (Lerner & Van Audenhove, 2011). Traffic congestion is a serious issue to cities today. One of China’s busiest roads, a 50-lane parking lot on the G4 Beijing-Hong Kong-Macau Expressway, has traffic jams that last for hours (Poon, 2015). This trend leads to the increase of fossil fuel dependency, the decrease of urban mobility, rising investment in road systems, sprawling land development, and consequently, a rapid decrease of our quality of life (Kemp & Stephani, 2011; Macário, 2011; Hoppe, 2014).
Environmental sustainability challenges of urban mobility

Major changes are necessary to make the urban mobility system more compatible with environmental sustainability. Many researches show that most of the environmental issues the world faces today, including global warming, air pollution, oil spills and acid rain, result from our fossil fuel dependence, especially in the transport sector (Union of Concerned Scientists, n.d.; Wee, Maat, & Bont, 2012). Over the past 20 years, about 75% of human-caused emissions have come from the burning of fossil fuels (U.S. Department of Energy, n.d.). Combustion-driven vehicles, as a significant contributor to urban pollution, create over 20% of the global carbon dioxide emissions (Burns, 2013; Harrington & McConnell, 2003). In addition, the population of combustion-engine vehicles has grown rapidly in recent decades. According to an analysis by Ward (2011), the number of vehicles in operation worldwide has significantly increased by around 35 million in just half a year – from 980 million units at the end of 2009 to over the 1 billion-unit mark in 2010.

In order to release cities from congestion, shifting mobility from the private car to public means while increasing revenues to public transport is the most common government policy. However, “this shift of market share can only be achieved by making urban public transport (UPT) more attractive and responsive to citizens’ needs, as these are also becoming more demanding as time passes and general access to information is made easier” (Maca´rio, 2000, p. 747). In addition, customer needs can be better satisfied by door-to-door, rather than station-to-station, transportation (Bunting, 2004). The current development of public transport, like the fashion of Bus Rapid Transit, needs wider roads, which means more land use, less safety and more difficulties for pedestrians crossing intersections (Netto, 2015).
2.2 ‘GREEN’ ALTERNATIVES

Recently, interest is growing in viable ‘green’ alternatives to city mobility. Over the past 20 years, various technological choices were under discussion in literature and policy-making, such as electric vehicles (EVs) and electric bicycles, in order to trim down fossil fuel dependency and to reduce the effect on the environment (Wee et al., 2012).

Electric vehicles (EVs)

According to Wee, Maat and Bont (2011), while having many advantages – such as electricity costs per kilometre being much lower than fuel costs per kilometre, and EVs not polluting locally and making almost no noise – whether EVs will become a success is hard to say. The relatively lower cost of electricity compared to fossil fuel could lead to an incentive to travel more, and a shift from public transport or slower modes (bike, foot, etc.) to the private car (Wee et al., 2011). On the other hand, as they discussed in their paper, EVs could increase transport resistance to some extent. The range of EVs would probably be limited compared with internal combustion engine (ICE) cars, and the time of recharging – three to four hours for a full charge (Kessler, 2015) – is much longer than refuelling a car, unless there are breakthroughs in battery technology. In 2014, an ultra-lightweight supercapacitor that can easily provide a high power output in a few minutes was invented by scientists from Queensland University of Technology (QUT) in Australia, meaning the time of recharging EVs would be extremely short and a fully-charged EV using this technology should be able to run a distance similar to a petrol-powered car (Macdonald, 2014). As nanotechnologists from QUT estimated, this technology could power battery-free electric cars within five years. In addition, recently, the UK government have tested a new road surface that can offer wireless charge to cars as they move along, and a similar idea is already in use in South Korea (Nield, 2015). While new road surface could solve charging issue of EVs, a citywide road surface improvement would be a large financial issue to both governments and individuals. Essentially, over the long term, a reasonable price and extreme convenience of EVs could lead to an increase of car ownership, which may affect land use (Wee et al., 2011).

E-bikes

With zero emissions, e-bikes are popular in the discussion of green alternatives, too. The usage of e-bikes has experienced rapid growth in Asia and Europe, and it has been estimated by industry representatives that around 1% of annual bicycle sales are of e-bikes (Fyhri & Fearnley, 2015). Compared with EVs, the smaller size of the battery pack on an e-bike is better for charging by renewable energy resources, which means a lower effect on the environment (“Electric bicycle”, 2015). With the new road surface technology, e-bikes can offer long-distance trips as same as cars. The e-bike is quicker, capable of longer trips over hilly routes, and a desirable alternative for people who are averse to cycling (Fyhri & Fearnley, 2015). However, for commuting, few people would choose e-bikes instead of cars to do long-distance trips, due to their relatively lower speed and less-comfortable driving experience, and for deliveries, the smaller the size of vehicle, the less luggage space would be
available. In Fyhri and Fearnley’s research (2015), it seems that e-biking would probably only replace other non-motorised travel, and have limited effect on motorised travel. Moreover, cars, as an example of positional goods, are probably used for psychological reasons (Wee et al., 2011), which means that, at an equivalent technology level, people would be more likely to choose EVs than e-bikes.

**Human-powered transport**

In the pursuit of the environmentally-friendly city, many cities have promoted human-powered transport (bicycles, etc.) as a primary form of urban transport. Human-powered transport, as a form of sustainable transportation, remains popular due to cost-saving, energy saving, leisure, physical exercise and environmentalism (“Transport”, 2015). According to Lindsay, Macmillan and Woodward (2011), the benefits of encouraging bicycle use heavily outweigh the costs of injury from road accidents. Shifting 5% of vehicle trips to cycling would annually reduce vehicle travel by about 223 million kilometres, save about 22 million litres of fuel and reduce transport-related greenhouse emissions by 0.4%. The bicycle offers an economic, comfortable, easy, and sustainable way of human mobility. Although bicycles have benefits for the environment and the individual, good bicycle infrastructure—which makes bicycling an easy and quick way to get around cities— is necessary to persuade people to ride bikes. In Auckland, due to its low-density urban development, there is no doubt that human-powered transport is unsuited to long-distance trips, especially for commuting purposes. However, low speed and no barrier between transport users and the environment make human-powered transport a perfect option for recreation, family touring and fitness.
2.3 POPULARITY OF BICYCLES IN MODERN CITIES

There are more than a billion bicycles in the world, twice the number of automobiles. In recent years, bike production has climbed to over 100 million per year (compared to 60 million cars) (Sibilski, 2015). Bicycles were introduced in the 19th century and since then have been and are employed for many uses: recreation, work, military, show, sport, etc. For example, in the USA, people use bikes for weight loss and wellbeing, because cycling burns 600 calories an hour, but in China and other countries people use bikes mostly for transportation needs (Admin, 2011).

A growing number of cities throughout the world are creating bicycle infrastructure to promote cycling.

Amsterdam, the Netherlands

With a population of 800,000, there are 881,000 bicycles in Amsterdam – the capital city of the Netherlands. Every day, each person travels by bike for 2.4kms on average. Travelling by bike in Amsterdam is more likely faster than by car (I amsterdam, 2017).

The Dutch were already building dedicated paths for cyclists in the 1890s and by 1911 owned more bicycles per capita than any other country in Europe. However, like other cities around world, the private motor vehicle became popular after World War II, which caused a huge rise in the number of deaths on the roads. After the Middle East oil crisis of 1973, the Dutch government started to improved cycling infrastructure (Magazine, 2013). The Dutch now have a total of 39,000kms of bicycle paths. Bicycle trips between home and public transport stations comprise about 50% of all trips, and 15% of all commuters walk to the station (Schaap, Harms, Kansen, & Wüst, 2016).

Figure 2.1. A typical Dutch bike path, Rotterdam (Emvee, 2010).

Figure 2.2. Bicycle lane, Dronten (Ashmann, 2011).
There are various types of cycle paths in the Netherlands. The typical bi-directional cycle path design (see Figure 2.2) is a roadway with a green verge in between, and side walk on the other side of cycle path. On low-volume traffic roads, vehicle-bicycle shared paths are commonly used, like Fietsstrook-type cycle lanes (see Figure 2.3) that may be used by motorists as well when other cars approach from the opposite direction. The cars must use them safely, however, and not crowd out the cyclists. For long-distance trips, the Dutch also have bicycle highway (see Figure 2.4) which separated from vehicle roads, allows cyclists to ride bikes on a relatively higher speed than on normal cycle paths.

In 2007, two fully functional automatic bike dispensers (see Figure 2.6) were put into service at Arnhem Zuid and Nijmegen-Lent railway stations. Several more automatic dispensers are planned near public transportation hubs. The machine can automatically rent out a bike in 15 seconds and then return it after use. It can be built underground or on the roof of a building, and contains 50-100 bicycles. The design won an award at the 2007 Spark Design & Architecture Awards.

There are three main types of bicycle routes: junction routes, themed routes and long-distance cycle routes (Landelijke Fietsroutes), which make travelling in, and throughout, the Netherlands by bike so easy. The LF network is a national cycle route constituted of long-distance, cross-border routes, about 4500 kilometres in total (Nederland Fietsland, 2017). Junction routes are linked to the national cycle route network (LF network). The former is designed for daily bicycle trips and the latter is perfect for multi-day cycle trips. Every junction has a number and a sign with next
junction’s number and distance, and a map showing nearby junctions, which allows people to easily design their own trips. The visual signage for cycling use only is available at every relevant junction (Bicycleandtour.com, 2016).

Figure 2.7. The visual signage for cycling in Dutch (Bicycleandtour.com, 2016).

Figure 2.8. The junction network in the Netherlands (OpenStreetMap, 2017).

The system of cycling routes now consists of more than 7600 junctions, covering over 30,000 kilometres of cycling routes throughout the country (See Figure 2.8). A cyclist can typically expect to cover between 15 and 18 kilometres, on average, in an hour by bike throughout most areas of the Netherlands (“Cycling in the Netherlands,” 2017).

In addition, the concept of a bike-friendly city is seriously considered in city planning and policy making, which leads to more cycling in the Netherlands. The needs of cyclists are taken into account at all stages of urban planning. Car use is unattractive in towns that have been designed with limited car access and limited (and decreasing over time) car parking. In contrast, bicycle parking is provided next to every shop and public transport station. The strict liability in the Netherlands makes car drivers more cautious around cyclists. Bicycle helmets are not commonly worn in the Netherlands, in fact, the Dutch Fietsersbond (Cyclists’ Union) summarised existing evidence and concluded that, for daily cycling activity, a compulsory helmet law would have a negative impact on population health (Dutch Fietsersbond, 2013). Densely populated
areas and flat terrain make most trips in the Netherlands short duration, with no sweat; no lycra or helmet needed. Dutch children are immersed in a world of cycling even before they can walk, and bicycles provide Dutch teenagers freedom of movement. Ninety percent of students cycle to class, and cycling class is a part of the school curriculum (Magazine, 2013). These benefits far outweigh the negative factors of wet and windy weather in the Netherlands. While it is true that a quarter of all deadly crashes in the Netherlands involve cyclists, statistically, people there are more likely to die by drowning than by cycling (Bakfiets en Meer, 2008).

**Copenhagen, Denmark**

Copenhagen is the capital city of Denmark, with a population of 1.3 million inhabitants. It is famous for biking culture and is now officially the first Bike City in the world. The Danes are well known for their love of cycling and cities all around the world are now looking at ways to copy this phenomenon.

Copenhagen has a long-standing cycling tradition dating back to the late 19th century, and half of the city’s current cycling infrastructure already existed in the 1970s. The numbers of cycling trips more than doubled between the 1980s and 2010s (“Cycling in Copenhagen,” 2017). Cycling is the most popular transport mode in Copenhagen, and 1.2 million kilometres of cycling trips happen every day (“Cycling in Copenhagen,” 2017). Fifty-five percent of people living in Copenhagen, working and studying, prefer to ride bikes in the morning (“Cycling in Copenhagen,” 2017).

All areas of Copenhagen have a coherent network of segregated lanes designated as cycle tracks. People prefer cycling because it is the quickest and easiest way to get around town (Ministry of Foreign Affairs of Denmark, n.d.). Bicycle infrastructure in Copenhagen currently includes about 350 kilometres of curb-segregated cycle tracks, 23 kilometres of on-street cycle lanes and 43 kilometres of off-street green bicycle routes running through parks and other green areas.

The Copenhagen-style cycle track (see Figure 2.9) has been recently established in New York and Melbourne. It is slightly elevated from the road, giving the cycle track its own curb, or cars parked along curbs become another curb to protect cyclists. The research (Gemzoe, 2010) shows that after every curb is established, there is an increase in cyclists by between 18 and 20%, and a decrease in cars by between 9 and 10%. However, a painted lane in the same place has no influence on the number of cars, and only creates an increase in the number of cyclists of between 5 and 7%.
As we can see in Figure 2.11, the inset map shows a 40kph speed limit area in grey, with main roads as thick blue lines and collector roads in dark red; the main map shows existing cycle tracks, the proposed cycle network and green cycle routes. The comparison of the two maps highlights the bicycle-network planning goal in Copenhagen, which has most of the green bicycle routes following the main collector roads, so that green routes provide cyclists with the quickest and most direct route, and encourage long-distance and recreational cycling.
In the cycle track priority plan 2002-2016 (See Figure 2.12), painted cycle lanes are used as a temporary measure, and the 2.5-metre-wide curb-segregated cycle tracks are supposed to be added to places that form links in the existing cycle track network, or have a high density of bicycle traffic. The green bicycle route, which focuses on recreation and commuting purposes, and provides short-cuts through the city and offers links with areas not connected, was adopted in 2000 and updated in 2006 (Nelson, 2006).
There are five road types in cities: freeways/interstates; arterials and major collectors; minor collectors; local roads; and parkways.

Traffic congestion always happens on freeways and major arterial roads, and barely happens on minor collectors, local roads and parkways. In addition, research shows that people hit by a vehicle traveling at 64km/h have an 80% risk of death, at 48km/h a 40% risk of death risk and at 32km/h have a 10% or 5% risk of death. Speed limits on minor collectors, local roads and parkways are mostly lower than 40km/h, which means traveling by human-powered vehicles on these types of roads is safer than on freeways and arterial roads. (This makes my project more feasible, and by linking existing road networks, we will not only make bicycle travelling for recreational purpose safer, but also give people travelling for commuting purposes a flexible choice to avoid traffic congestion.)

The speed limits for vehicles also have an influence on the choice of bicycle lane types. The Copenhagen Bicycle Planning Guide, which is also used in the Copenhagen-style bicycle lanes project in Melbourne, shows that separated lanes are used only when car speeds exceed 50km/h. Between 10-30km/h there is no separation, and from 30-50km/h painted lanes are used.

However, cycling culture can easily be threatened by car culture, even in Copenhagen. Teaching children to cycle is a way of keeping cycling culture alive; continued positive experiences of cycling could create a dependence on cycling, while children who do not cycle are not likely to become cyclists as adults (Ruby & Andersen, n.d.).
Xiamen, China

After a dramatic increase of car ownership among China’s urbanites, bicycles are once again becoming a more and more popular way of getting around, as the result of heavy traffic jams, and people’s increasing attention on the environment and their health. Xiamen is famous for its South Putuo Buddhist Temple, the island of Gulang Yu, colonial architecture and beaches. In 2017, it added another attraction to the list with an eight-kilometre cycling path, which is the world’s longest elevated bike skyway (Foxe, 2017). The bicycle bridge has eleven entry and exit points, covers five major residential areas and three business centres, provides easy access to public transportation, shopping malls and public buildings to commuters in the city, and can handle 2023 bikes at a time (Garfield, 2017) with a maximum speed of 24 kilometres per hour (Hickman, 2017).

With the development of the cycleway, a bicycle sharing system is quickly developing. The ‘non-docking’ platform, which allows users to locate and unlock a bike any time and anywhere through an online password, makes Ofo now the most popular bike sharing system in China. To date, Ofo – one of the biggest companies in the bike-sharing market – has connected about 10 million registered users with over 1,000,000 bikes across 46 cities in China (Shu, 2017). However, the increase in the number of shared bicycles and the flexibility of parking has led to chaos and a huge occupation of public space. Part of the problem is that bicycle parking has not been given the necessary attention in urban planning and area use in China. The present solution in other countries is to create new bicycle parking facilities, such as underground bike vaults in Japan (Springer & Han, 2016) and the ‘Bike Hanger’ in Korea (Masoner, 2011).
2.4 THEORIES OF CITY PLANNING

New Urbanism

The excellent urban design practices before the rise of the motor vehicle after World War II strongly effect New Urbanism, which includes ten basic principles such as traditional neighbourhood design (TND) (see Figure 2.17) and transit-oriented development (TOD) (Kelbaugh, 2002). The principles of New Urbanism can be summarised in two concepts: building a sense of community and the development of ecological practices (NewUrbanism.org, n.d.). New Urbanism calls for a return to clustered, mixed-use, walkable neighborhoods with grid-like street patterns (Steuteville, Langdon, & Special contributors, 2003).

New Urbanism is considered by communities to be an effective strategy for community development. In Hikichi’s article (2003), though there are many other choices for cities and communities, New Urbanism is a feasible option. He argues that New Urbanism is a hopeful option for cities in next 50 years, since it is likely to better deal with the current trends of rising traffic congestion, urban sprawl and environmental problems.

However, according to Handy (1996), planners and policy-makers cannot ask residents to do something that they are completely reject doing. Travel behaviour is an indicator of the quality of choices available. The results of a study of New Urbanism in Los Angeles (McLaughlin & Allison, n.d.) shows that residents in Playa Vista have slightly lower car ownership than individuals living in Mar Vista, but they have more car usage, which means New Urbanism is not likely to be successful in every environment. In Kelbaugh’s (2000) article, New Urbanism is a precedent and fully includes sustainable order, which is suitable for cities that lack continuous urban fabric but have the financial wherewithal to build it, such as American cities. However, he argues that because community design consists of complicated situations, New Urbanism has some inevitable, structural limitations (Kelbaugh, 2007).
STRENGTHS

• New Urbanism can deal with rising traffic congestion, urban sprawl and environmental issues effectively.

WEAKNESSES

• New Urbanism, which is a form of centrally planned, large-scale development, maintains general design principles instead of considers local situations.

• New Urbanism ignores consumer preference. Cities have moved towards car-oriented development because people's the requirement of vehicle is increasing.

• The effectiveness of New Urbanism solutions to various issues in modern cities lacks of statistical evidence.

The compact city

The compact city concept conveys the opposite of urban sprawl, which is more energy efficient and less polluting because residents live closer to shops and work places so they can choose sustainable transport, such as walking, biking and public transport (Neuman, 2005). The concept of the compact city, which has much positive impact on sustainable development (Crookston, Clarke, & Averley, 2003), is popular, especially in European communities (European Commission, 2007).

Some architects believe that compact cities are an important part of a sustainable future. There is a tight relationship between the 3Ds (density, diversity and design) of the built environment and travel demand (Cervero & Kockelman, 1997). For example, Hillman (1996) concedes that residents in high-density cities will be influenced on their individual lifestyles in a positive way. He believes that compacting cities can reduce the consumption of fossil fuels, so that citizens could have lower expenditure in transport and heating, and better environment.

However, there is no reliable evidence showing the relationship between higher densities and reduced automobile trips. The needs of people today, such as greenery, sense of safety, good schools and quiet streets, exist in both low-density suburbs and the densest cities, such as Barcelona, Prague, Amsterdam and San Francisco (Neuman, 2003). The compact city is neither a necessary or sufficient condition for a city to be sustainable and the attempt to make cities more sustainable only by using urban form strategies is counterproductive (Burton, 2000; Neuman, 2005).

STRENGTHS

• Compact city has positive influence on sustainable development because people live in denser cities tend to choose sustainable transports that have lower consumption of fossil fuels, heating and pollution.
**WEAKNESSES**

- Only using urban form strategy is insufficient to reduce the traffic effect of increasing population density.

![Figure 2.18. The compact city model (Design Buildings Wiki, 2017).](image)

**Human-centred urbanism**

Copenhagen, Denmark, in the 1970s was modernising with a significantly car-centric mentality; however, now it is welcoming for both pedestrians and cyclists because of the theory of human-centred urbanism that Jan Gehl spearheaded. Jan Gehl (2013) emphasises that physical environment is a factor that effects outdoor activities to various levels and in myriad ways. In Gehl’s book *Life Between Buildings: Using Public Space* (1987), outdoor activities are divided into three types: necessary activities, optional activities and social activities. It is possible to change the spectrum of human activities by enhancing the environment, due to the fact that optional activities are highly influenced by different places and situations. Gehl (1987) offers specific design recommendations: connected and small blocks, direct paths, permeable buildings, ample greenery. He also mentioned that the most vibrant areas of the city are created by ‘soft edges’, especially places where people could sit and face the pedestrian flows. Soft edges link private and public space (Gehl, 1987).

Because of increase of gas prices and concern of health, people are encouraged to be more active, and residents in city gradually realise that riding bikes around city is faster than driving vehicles and getting stuck in traffic congestion (Bramley, 2014).
Most of Gehl’s work has focused on the bicycle to make residents can easily travel in cities without individual cars (Bramley, 2014). With so many successful city planning projects, such as Copenhagen’s city centres, Melbourne’s city centre redevelopment (Gehl & Gemzoe, 1996), and London’s ‘cycle superhighway’ plans and so on (Bramley, 2014), Jan Gehl’s philosophy has been proved to be a practical theory for sustainable urban planning.

**STRENGTHS**

- As asserting that planning from the perspective and scale of the person Instead of planning from aerial photographs, Human-centred Urbanism avoids the urban planning fail in using as the scale of the human.

**WEAKNESSES**

- Human-centred Urbanism has its limitations when it comes to rich ecological sites where people’s views and concerns are not important compared with environmental challenges.
2.5 DESIGN STRATEGIES & PRINCIPLES

Local Path Design Guide (Resilio Studio & MRCagney, 2016)

The Local Path Design Guide illustrates what are local paths and how they connect to Auckland's wider transport network; it includes design principles, a path network planning guide and the application of physical infrastructure. The book outlines design principles that are safe, connected, accessible, comfortable and enabling, and performance standards that can provide quantitative and measurable benchmarks to design. Moreover, the network planning section describes a planning process of local path development that provides designers with a clear idea of how to design a path network step-by-step. In addition, the book provides technical guidance for tools required in the design of a local path through a park, giving designers measurable benchmarks when designing cycling and walking connections across the region.

Performance standards

• The maximum design speed for cyclists on local paths in parks and open spaces is 20km/h.

• Pedestrian-bicycle shared path’s desirable width is 3 meters (see Figure 2.20).

• The structure of the walking/cycling bridges and boardwalks is typically either timber or steel. The surface is typically timber but can be concrete or steel.

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![Preferred Widths Diagram](image)

Figure 2.20. Pathway preferred width (Resilio Studio & MRCagney, 2016).

The NZCT Design Guide compiles information about construction techniques from many existing guides, and will help designers to create appropriate cycle trails that have good access to their natural surroundings and meet the expectations of the target audience. The gradient requirements, paving materials and space for cyclists and pedestrians that are illustrated in the book will provide a design standard for our cycleway project.

Performance standards

- Figure 2.21 shows the operating space required for cyclists.

- Table 2.1 & 2.2 show the gradient requirements for on-road and off-road trails. Cycle path for normal cyclists should match the gradient requirement for trail under grade 3.
<table>
<thead>
<tr>
<th>Trail Grade</th>
<th>Main uphill gradient range</th>
<th>Steeper slopes up to 200 m long</th>
<th>Steeper slopes up to 20 m long</th>
<th>Maximum Downhill Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 2.5 degrees for 98% of length</td>
<td>2.5 – 3.5 degrees</td>
<td>3.5 – 4.5 degrees</td>
<td>4.5 degrees</td>
</tr>
<tr>
<td>2</td>
<td>0 – 4 degrees for 95% of length</td>
<td>4.5 – 5 degrees</td>
<td>5 – 7 degrees</td>
<td>7 degrees</td>
</tr>
<tr>
<td>3</td>
<td>0 – 6 degrees for 90% of length</td>
<td>6.5 – 8 degrees</td>
<td>8 – 10 degrees</td>
<td>10 degrees</td>
</tr>
<tr>
<td>4</td>
<td>0 – 8 degrees for 90% of length</td>
<td>9 – 10 degrees</td>
<td>10 – 13 degrees</td>
<td>13 degrees</td>
</tr>
<tr>
<td>5</td>
<td>0 – 10 degrees for 90% of length</td>
<td>12 – 15 degrees</td>
<td>15 – 18 degrees</td>
<td>18 degrees</td>
</tr>
</tbody>
</table>

**Notes:**
1. This table applies to on-road sealed trails and off-road sealed (concrete or asphalt) trails.
2. Uphill sections of trail that are steeper than these gradient criteria should only be one grade harder and only in sections of up to 100 m length. It is undesirable to have harder sections of trail as some riders are likely to be forced to walk these sections.
3. Maximum downhill gradient applicable for 100 m and only if trail is designed and promoted to be ridden in one direction.

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<table>
<thead>
<tr>
<th>Trail Grade</th>
<th>Main uphill gradient range</th>
<th>Steeper slopes up to 100 m long</th>
<th>Steeper slopes up to 10 m long</th>
<th>Maximum Downhill Gradient for slopes up to 100 m long</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 2 degrees for 98% of length</td>
<td>2 – 3 degrees</td>
<td>3 – 4 degrees</td>
<td>4 degrees</td>
</tr>
<tr>
<td>2</td>
<td>0 – 3.5 degrees for 95% of length</td>
<td>3.5 – 5 degrees</td>
<td>5 – 6 degrees</td>
<td>6 degrees</td>
</tr>
<tr>
<td>3</td>
<td>0 – 5 degrees for 90% of length</td>
<td>5 – 7 degrees</td>
<td>7 – 8 degrees</td>
<td>8 degrees</td>
</tr>
<tr>
<td>4</td>
<td>0 – 6.5 degrees for 90% of length</td>
<td>6.5 – 8 degrees</td>
<td>8 – 10 degrees</td>
<td>10 degrees</td>
</tr>
<tr>
<td>5</td>
<td>0 – 8 degrees for 90% of length</td>
<td>8 – 10 degrees</td>
<td>10 – 14 degrees</td>
<td>14 degrees</td>
</tr>
<tr>
<td>6</td>
<td>0 – 10 degrees for 90% of length</td>
<td>10 – 15 degrees</td>
<td>15 – 30 degrees</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. This table applies to off-road unsealed trails and gravel roads.
2. Uphill sections of trail that are steeper than these gradient criteria should only be one grade harder and only in sections of up to 100 m length. It is undesirable to have harder sections of trail as some riders are likely to be forced to walk these sections.
3. Maximum downhill gradient applicable only if trail is designed and promoted to be ridden in one direction.
4. IMBA recommends a maximum gradient of 10% (5.7 degrees) to ensure a trail is sustainable. Steeper trails will require more maintenance due to skidding tyres and water scour.

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Table 2.1. The gradient requirements for on-road trail (Viastrada Ltd, 2015).

Table 2.2. The gradient requirements for off-road trail (Viastrada Ltd, 2015).
2.6 CASE STUDIES

There are few successful examples of cycleway developments that use different materials, surfaces and dimensions from the traditional type of cycleway. The three case studies investigated in this thesis, which provide a new design idea of cycleway development, integrate public space and bicycle networks, and link on-ground cycle networks with elevated cycleways to attain a coherent cycle network in a modern city, not only improving accessibility and the connection of cycling to the city, but also decreasing the stress of road traffic to improve the quality of urban mobility. The following case studies are:

- The Bicycle Snake, Copenhagen
- The Bicycle Skyway, Xiamen
- The Lightpath, Auckland

This thesis will discuss each case study and establish the common threads to identify the strengths and weaknesses. Each case study will unveil design themes and strategies following an analytical process, which will then be rationalised. The design principles and strategies extracted from the examination will form a set of criteria, to be applied to cycle network design in Auckland.
The Bicycle Snake, Copenhagen

Engineer: Rambøll
Architect: DISSING+WEITLING Architecture
Date: June 2014
Cost: DKK 32million (NZD 7.11million)
Total length: 235m
Width: 4m

The Bicycle Snake (Cykelslangen) is a 235-metre-long, four-metre-wide pedestrian and cycle bridge, which includes a 190-metre bridge and a 30-metre ramp, and links from the Fisketorvet Shopping Centre, out over the harbour basin, and in between the blocks at Kalvebod Brygge, to the Bryggebro Bridge (See Figure 2.22). Parts of The Bicycle Snake have been designed to extend out over the water and elevated six-to-seven metres above the sea's surface and in between Hotel Copenhagen Island, Aller Huset and Atrium, above the pedestrian traffic on Vester Brogade, all at first-floor level (see Figure 2.23). In order to achieve a light, slender design, The Bicycle Snake is built in steel. The orange-coloured surface (see Figure 2.24) and the built-in lighting enrich the area as a bright visual element in both day and night (Frandsen, 2015).

The design of the Bicycle Snake alleviated the poor cycle transit at the Dybbølsbro Bridge and avoided conflicts between cyclists and pedestrians in the area around Fisketorvet Shopping Centre (DISSING+WEITLING Architecture, 2014; Frandsen, 2015). The Bicycle Snake provides cyclists with both an aesthetic and a dynamic experience. Around 12,500 cyclists daily cross Bryggebroen (Quay Bridge) and the area around Fisketorvet (DISSING+WEITLING Architecture, 2014).

**Strengths:** This urban project is made with as few obstacles as possible, and there is a strong emphasis on safety, security and comfort. The Bicycle Snake decreases on-ground cyclists and pedestrian traffic, making the area around Fisketorvet a more recreational space, raising the overall quality of the area. It will generate a better environment with less congestion and more health, which will not only benefit cyclists, but also benefit other road users, such as pedestrians and vehicle drivers. The orange surface emphasises recognition, and the steel material reduces the cost and enhances the appearance of the structure. The steel ramp provides a unique harbour outlook during sunny days and a shelter during rainy days. The concepts for the different structures, which focus on increasing comfort, bringing down the price, ensuring recognition and increasing safety and security, can be applied to the development of many urban cycle networks.
Weaknesses: The elevated cycleway may have a low usage rate in Auckland, as unlike Copenhagen, Auckland lacks a connected cycle network and widely accepted bicycle culture. Besides, though a steel cycleway can provide a good cycling experience for short-distance cycling trips, it is not suitable for long-distance cycling trips because of the much higher cost than an on-ground cycleway.
The Bicycle Skyway, Xiamen

Engineer: JSTI Engineering
Architect: DISSING+WEITLING Architecture
Date: 2016-2017
Total length: 7600m
Width: 4.8m

Bicycle culture in Xiamen is strong, and has been for decades. Xiamen is an island-bound port city in the southeastern province of Fujian. As a tourist-friendly city, it has relatively light air pollution and a small population (3.531 million) compared to other major Chinese cities (“Xiamen”, 2017; Hickman, 2017). Motorcycles and mopeds, which are popular in other cities in China, have been outlawed in Xiamen since the 1990s. Now, Xiamen is a city mostly reliant on bicycles, so is an ideal location to build China’s first long-distance elevated cycleway.

The Xiamen Bicycle Skyway is the world’s longest elevated bicycle path; 7.6 kilometres long, 4.8 metres wide and elevated five metres above the road (Gibson, 2017). It is integrated with the BRT system (public bus transit system), built beneath the BRT lanes, and links the city’s five major residential and three business districts with 11 designated exits/on ramps. Along the route, cyclists have direct access to 11 bus stations and two subway stops, making it fully possible to get around almost the entire city without taking a taxi or private car. Furthermore, the cycleway can handle 2023 bikes at a time with a maximum speed of 24 kilometres per hour (Hickman, 2017). If the cycleway becomes too crowded with cyclists and pedestrians, high-tech gates at its on-ramps will automatically close (Eldredge, 2017). Pedestrian bridges, ramps, roundabouts, bicycle parking and bicycle service pavilions are also included along the route (see Figure 2.27). Moreover, a bike-sharing system is used along the cycleway. More than 300 shared bikes are available along the route, there are 253 parking spaces for private bikes on seven platforms, 1.5 metres of curved guardrail decrease the fear of heights and 30,000 lights make the structure safe for cycling at night (Gaete, 2017).

Strengths: This project integrates different transportation methods and achieves multiple use of the cycleway. Bicycle parking along the cycleway provides a new solution to the huge occupation of public space. Clipping on the existing BRT route decreases the cost of the cycleway. Through the structure of the cycleway and the facilities along the cycle route, we can easily see, designers considered accessibility, mobility and connectivity to create a good bicycle infrastructure for the city. These design strategies can be explored in Auckland’s cycleway development, to create unique a cycleway that raises the connectivity of the bicycle network.
**Weaknesses:** With such a long distance, high-tech facilities and high usage rate, the cycleway will need plenty of labour and money to do regular maintenance and management.
The Lightpath, Auckland

Architect: Hawkins & Novare Design
Date: 2015-2016
Cost: NZD 18 million
Total length: 160m
Width: 4m

The Nelson Street Cycleway was built to form part of the cycle network in Auckland, connecting the shared off-road pedestrian and cycling path on Upper Queen Street to the waterfront at Quay Street. The Lightpath is a shared walking and cycling path from Canada Street to the Union/Nelson Street intersection via a bridge and the disused Nelson Street off-ramp. It is part of the Nelson Street Cycleway, which continues down Nelson Street as a two-way cycle path and part of a new cycleway planned for the city centre. In order to give the cycleway a modern and 'distinctly New Zealand' look, the design includes LED lights, which line the safety barriers and pulse as people pass them (See Figure 2.27), as well as a strong magenta surface colour that fades out at both ends in a Maori design (See Figure 2.28). Since opening on the 3rd of December 2015, there have been 848 cycle journeys per day on average on the Lightpath. Compared with February 2014, the number of people cycling in Grafton Gully increase 38% in February 2015 (“Nelson Street Cycleway – Te Ara| Whiti (Light Path),” 2015).

Strengths: This project uses unique a structure and surface material, turns the old Nelson Street motorway off-ramp into an amazing Auckland attraction, delivering an active transport link for Auckland. The physical separation removes cyclists and pedestrians from general vehicle traffic lanes, enhancing safety.

Weaknesses: Although the special-coloured surface on the cycle path is a creative design, designers forgot to consider Auckland's unique weather. As a result of this oversight, just over a year on from when the Lightpath was first opened its once vibrant magenta pink has faded to more of a dirty pastel. Auckland Council had to spend $115,000 on repainting a layer of UV protection to protect the cycleway from the natural elements (Miller, 2017). A cycleway project must include comprehensive analysis of context and proper choice of materials and structure, to ensure the design is a long-term solution and the infrastructure has sustainable value.
Figure 2.32. LED lights on Lightpath (“Nelson Street Cycleway – Te Ara| Whiti (Light Path),” 2015).

Figure 2.33. Maori design on Lightpath (Auckland Council, 2016).

Figure 2.34. Faded pink surface of Lightpath (Carnegie, 2016).
2.7 SUMMARY

The current situation of urban mobility systems indicates that the system is highly motorised, and moving away from sustainability. Major changes are necessary to make the urban mobility system more compatible with environmental sustainability. In order to release cities from congestion, shifting mobility from the private car to public means while increasing revenues to public transport is the most common government policy. However, the current development of public transport not only cannot satisfy citizen’s needs of door-to-door service, also leads to more land use and conflicts between pedestrians and vehicles.

In order to trim down fossil fuel dependency and to reduce the effect on the environment, various technological choices were under discussion in literature and policy-making, such as EVs, E-bikes and human-powered transport. After compared three popular ‘green’ alternatives, except human-powered transport, though other alternatives can reduce environmental pollution to some extent, cannot decrease car use effectively.

Amsterdam, Copenhagen and Xiamen’s development of bicycle infrastructure are relatively more mature than Auckland’s. In these three cities, coherent bicycle network provides safe and unblocked cycling experience to cyclists, the construction of bicycle path has clear standard, and bicycle infrastructure, like bicycle parking enhances accessibility, convenience and connectivity.

Theories of city planning discussed three popular theories of urban planning, and identified Human-centred urbanism is suitable for our design goal. New Urbanism is utopian, focuses on large-scale planning and ignores the local situation of design site. The compact city cannot reduce traffic congestion that increasing while the rise of population density. Human-centred urbanism has positive influence on city’s liveability. A lot of Gehl’s work has focused on the bicycle to make residents can easily travel in cities without individual cars (Bramley, 2014). Human-centred Urbanism can be a basic theory to guide the design of Auckland bicycle network.

With the development of bicycle infrastructure around world, many case studies that use different materials, surfaces, dimensions and technologies from the traditional type of cycleway have been built. A series of design strategies and design principles can be extracted and applied to Auckland’s bicycle network development at different scales.

This thesis will utilise theoretical findings, design strategies, and principles explored from the literature review to develop an independent cycle network along existing transport infrastructure and waterfront, linking open green spaces, that has potential to extend into a connected cycle network which covers the whole Auckland region.
3.0 SITE SELECTION

Context analysis
Landscape analysis
Experiential analysis
Key findings
3.1 CONTEXT ANALYSIS

The Auckland CBD is the biggest labour market, the largest commercial area and has the highest population density in the Auckland region. According to Statistics NZ’s Business Demography Employment Data (2017), about 15% of the total employment is in the city centre, but jobs are spread around the entire Auckland region. Interestingly, in the Map of Commuting Length by Residential Area 2013 (See Figure 3.1), the average distance for commuting and the distance between home and city centre has a positive correlation. In addition, the Map of Business Density in Auckland 2013 (See Figure 3.2) shows that the city centre has the highest density, with some satellite centres like Takapuna and New Lynn also having high density. Moreover, after integrating the information of the Population Density Map 2006-2013 (See Figure 3.3) and the Population Density Change Map 2006-2013 (See Figure 3.4), the Auckland city centre not only has the highest density, but also has the fastest density growth in the Auckland region.

![Figure 3.1. Map of Commuting Length by Residential Area 2013 (Nunns, 2015).](image1)

![Figure 3.2. Map of Business Density in Auckland 2013 (Nunns, 2015).](image2)

![Figure 3.3. Total population per square km (Matt L, 2013).](image3)

![Figure 3.4. Population Density Change Map 2006-2013 (Matt L, 2013).](image4)
Furthermore, according to Bertaud’s talk in Auckland (n.d.), there are four different models for the urban labour market: the classic monocentric model, the polycentric or dispersed model; the composite model; and the ‘urban village’ model (see Figure 3.5). Auckland is clearly a ‘composite’ city, which has a strong and developing city centre, but also a lot of employments spread around other metropolitan centres, industrial parks, local shops and so on. The CBD is an important commuting destination in the Auckland region.

As a result of the factors above, the CBD is one of the existing Auckland Transport focus areas for creating bicycle infrastructure, and most of the recent Auckland urban cycleway projects are focusing on connecting the CBD and surrounding areas (NZ Transport Agency, 2015) (See Figure 3.6).
3.2 LANDSCAPE ANALYSIS

Cycling catchment

The concept of catchment area is used by researchers to illustrate the spatial area that most transit users are comfortable to reach from a public transit stop or station (Flamm & Rivasplata, 2013).

The 800m-radius circle represents a convenient 10-minute walking catchment for most people in a community (Munro, 2009). The 800m circle shows a general journey; there are many factors that can affect catchment. In Flamm and Rivasplata’s research of public transit catchment areas, they found that the real distance of bicycle trips to reach transit is much longer than most cyclists expect when cycling to and from transit (2013). Munro says in his article (2009), perceived safety, quality and attraction of route, climate and topography can make big influence on pedestrian activity.

The same concept can be used in the cycling catchment. The average cycling speed is approximately three times faster than walking speed, so the distance is about three times longer (Schaap, Harms, Kansen, & Wüst, 2016). According to Auckland Transport (2017), ideally, cycleways in a 15-minute cycling catchment centred on train, bus, and ferry stations (See Figure 3.8) in the Auckland region could benefit 52% of the total Auckland population. Improving cycling connections to stations will help to maximise that investment and make the stations easily accessible to many more neighbourhoods, reducing the need for park-and-ride facilities.
As we can see from Figure ##, catchments are mostly connected, and the CBD is the central area in the Auckland urban area. The distances between the CBD and other areas are relatively short, which means if we build a connected bicycle network in the CBD, it will have an influence on, and can link, areas around the CBD.

However, the distance must be measured according to the existing street patterns, connecting all points that have the same distance from centre of the circle. An isochrone better represents the actual catchment than a circle. In the book Cycling and Walking: The Grease in our Mobility Chain (Ministry of Infrastructure and the Environment, 2016), the authors suggest that the actual catchment would probably be changed if we took the waiting time and other factors into consideration (see Figure 3.9).
**Geography**

In New Zealand Cycle Trail Design Guide (2015), off-road cycle trails are divided into six grades, from 1-6 representing easiest to extreme (See Figure 3.10), on-road cycle trails are divided into five grades, from 1-5 representing easiest to expert (see Figure 3.11). The proper cycle routes can be recognised or built on the basis of the gradient requirements of off-road and on-road trails.

Although Auckland has a hilly topography, there are a lot of areas with a slope of less than 5%, and some of them connect to each other and link to the CBD and its neighbourhoods. As shown in Figure 3.12, the loop, with a slope of less than 5%, starts from Westhaven, which connects with the Harbour Bridge, through Ponsonby shopping centre, Karangahape Rd, Auckland Domain, Newmarket shopping centre, Dove-Myer Robinson Park (Parnell Rose Garden), Britomart Transport Centre, Victoria Park and ends back at Westhaven. However, we can also see gaps, which have high gradients, in the loop, which may lead to the cycle route failing in connectivity. In a further study, detailed research with experiential analysis of each road, especially the gaps, is necessary.

<table>
<thead>
<tr>
<th>Trail Grade</th>
<th>Main uphill gradient range</th>
<th>Steeper slopes up to 100 m long</th>
<th>Steeper slopes up to 10 m long</th>
<th>Maximum Downhill Gradient for slopes up to 100 m long</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 2 degrees for 98% of length</td>
<td>2 – 3 degrees</td>
<td>3 – 4 degrees</td>
<td>4 degrees</td>
</tr>
<tr>
<td>2</td>
<td>0 – 3.5 degrees for 95% of length</td>
<td>3.5 – 5 degrees</td>
<td>5 – 6 degrees</td>
<td>6 degrees</td>
</tr>
<tr>
<td>3</td>
<td>0 – 5 degrees for 90% of length</td>
<td>5 – 7 degrees</td>
<td>7 – 8 degrees</td>
<td>8 degrees</td>
</tr>
<tr>
<td>4</td>
<td>0 – 6.5 degrees for 90% of length</td>
<td>6.5 – 8 degrees</td>
<td>8 – 10 degrees</td>
<td>10 degrees</td>
</tr>
<tr>
<td>5</td>
<td>0 – 8 degrees for 90% of length</td>
<td>8 – 10 degrees</td>
<td>10 – 14 degrees</td>
<td>14 degrees</td>
</tr>
<tr>
<td>6</td>
<td>0 – 10 degrees for 90% of length</td>
<td>10 – 15 degrees</td>
<td>15 – 30 degrees</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. This table applies to off-road unsealed trails and gravel roads.
2. Uphill sections of trail that are steeper than these gradient criteria should only be one grade harder and only in sections of up to 100 m length. It is undesirable to have harder sections of trail as some riders are likely to be forced to walk these sections.
3. Maximum downhill gradient applicable only if trail is designed and promoted to be ridden in one direction.
4. IMBA recommends a maximum gradient of 10% (5.7 degrees) to ensure a trail is sustainable. Steeper trails will require more maintenance due to skidding tyres and water scour.

Figure 3.10. Gradients requirement of off-road trails (Ministry of Business Innovation and Employment, 2015).
<table>
<thead>
<tr>
<th>Trail Grade</th>
<th>Main uphill gradient range</th>
<th>Steeper slopes up to 200 m long</th>
<th>Steeper slopes up to 20 m long</th>
<th>Maximum Downhill Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 2.5 degrees for 98% of length</td>
<td>2.5 – 3.5 degrees</td>
<td>3.5 – 4.5 degrees</td>
<td>4.5 degrees</td>
</tr>
<tr>
<td>2</td>
<td>0 – 4 degrees for 95% of length</td>
<td>4.5 – 5 degrees</td>
<td>5 – 7 degrees</td>
<td>7 degrees</td>
</tr>
<tr>
<td>3</td>
<td>0 – 6 degrees for 90% of length</td>
<td>6.5 – 8 degrees</td>
<td>8 – 10 degrees</td>
<td>10 degrees</td>
</tr>
<tr>
<td>4</td>
<td>0 – 8 degrees for 90% of length</td>
<td>9 – 10 degrees</td>
<td>10 – 13 degrees</td>
<td>13 degrees</td>
</tr>
<tr>
<td>5</td>
<td>0 – 10 degrees for 90% of length</td>
<td>12 – 15 degrees</td>
<td>15 – 18 degrees</td>
<td>18 degrees</td>
</tr>
</tbody>
</table>

**Notes:**
1. This table applies to on-road sealed trails and off-road sealed (concrete or asphalt) trails.
2. Uphill sections of trail that are steeper than these gradient criteria should only be one grade harder and only in sections of up to 100 m length. It is undesirable to have harder sections of trail as some riders are likely to be forced to walk these sections.
3. Maximum downhill gradient applicable for 100 m and only if trail is designed and promoted to be ridden in one direction.

Figure 3.11. Gradients requirement of on-road trails (Ministry of Business Innovation and Employment, 2015).

Figure 3.12. GIS map of slope in CBD and the loop of slope less than 5% (Authors own, 2017).
3.3 EXPERIENTIAL ANALYSIS

Through experiential analysis, designers can grow to understand the relationship between the proposed cycle route and surroundings, and how people use their city. As a design project based on Jan Gehl’s Human-centred Urbanism, walking through and observing the design site from a human scale is important. It is important to know how the bicycle infrastructure, and people and their behaviour affect each other. Experiential analysis has the potential to help a designer, as a visitor, to read the place through a local community perspective and to understand its potential and issues. We can then understand how we can use design as a way to invite people to ride bikes, providing sustainable mobility in Auckland.

Observations

- There are both on-road segregated cycle lanes and off-road cycle paths, and pedestrian-bicycle shared paths along coastlines, but the big altitude difference between the waterfront and the inner city, and the lack of effective connections discourage walking and cycling through the CBD.

- Transport relies mainly on vehicles, except in certain recreational areas.

- The real distances between attractions like green open spaces, shopping centres and the waterfront are mostly longer than 15-minute cycling, due to factors that time-wasting on roads with big gradient, waiting time at intersections and the limit of existing bicycle network’s highly dependence of road network.

- Cycleways near the waterfront and public recreational places are more likely to be used; even more children and teenagers use bicycle facilities for recreation on the weekends.

- The gaps discovered from GIS mapping are connected by Karangahape Rd, above Southern Motorway 1, and Grafton Bridge above North-Western Motorway 16.
Figure 3.13. Experiential analysis, Auckland CBD (Authors own, 2017).
3.4 KEY FINDINGS

Based on context analysis, landscape analysis and experiential analysis, it is obvious that the bicycle network in the Auckland CBD is still disconnected after many bicycle facilities have been built. On the other hand, these analyses have proved that the bicycle network in the CBD has a good potential to encourage people to ride bikes if we could improve accessibility and connectivity of bicycle network to open spaces, the waterfront and commercial areas.

Four main findings are:

- Although Auckland has a hilly topography, there are a lot of areas with a slope of less than 5% (see Figure 3.14.2), and some of them directly connect to each other and link the CBD and its surroundings (see Figure 3.14.1).

- The CBD has high density of attractions (see Figure 3.14.3), like transport centres, waterfront views, shops, restaurants and open green spaces, but doesn’t have a proper corridor for pedestrians and cyclists to reach them yet.

- There are existing connections above motorways to make both motorway and on-ground road traffic continuous (see Figure 3.14.4), and those connections could fill the gaps in the loop that are suitable for cycling.

- There are cycleways already in the loop, all we need to do is link them (see Figure 3.14.5).

Figure 3.14. Site analysis, Auckland CBD (Authors own, 2017)
4.0 Design

Design scope & objectives

Initial tests

Design speculations

Summary of design
4.1 DESIGN SCOPE & OBJECTIVES

This chapter will focus on the experimental design of the site (Auckland CBD) through comparative design principles and strategies extracted from the literature review. The design investigation will explore viable options for solving issues of accessibility, connectivity and safety with the development of bicycle infrastructure.

Objectives:

- Increase connectivity of the bicycle network in Auckland’s CBD, enhance connections between open green spaces and the waterfront.

- Develop recreational spaces with cycling training and bicycle parking areas while using urban marginal space.

- Create sustainable bicycle infrastructure with potential to keep step with technology development, the user’s expectations and proposed urban projects related to the project in the future.

The aim of this investigation is to develop a bicycle infrastructure that is an independent network in the Auckland CBD and responsive to Auckland’s contemporary challenges. The speculative design model could potentially act as a catalyst in the wider Auckland urban region.
4.2 INITIAL TESTS

Based on analysis above, gaps along the loop is the problem that needs to be solved when designers design the site. Diagrams (see Figure 4.1 & 4.2) show all slopes of roads that the cycleway may go through. The two test designs are solutions that could make cycling along the route easier.

![Figure 4.1. Gradients calculation](Authors own, 2017).

![Figure 4.2. Gradients calculation](Authors own, 2017).

**Conceptual scheme 1**

**Main strategy:** bypassing the gaps with on-road bicycle lanes through surrounding low-traffic-volume roads.

Due to the section of Currant Street between Westhaven and Ponsonby shopping centre having an extremely steep gradient, the route could be changed to Sarsfield Street, and go back to Ponsonby shopping centre along Jervois Road. In this way, the route would get about 3.3km (more than 15 minutes cycling) extra distance. The route going through a residential area could benefit residents, but is not helpful to the aim of a design that connects recreational areas because of the time-wasting long-distance deviation (see Figure 4.3).

In addition, there is a large altitude difference around the Parnell Road and Davis Cres intersection. In order to avoiding this gap, the route could go through Auckland Domain. Cyclists could ride bikes directly from Park Road to Parnell shopping centre through the pleasant surroundings of Auckland Domain (see Figure 4.4). This change not only shortens the distance between two attractions, skipping a gap, but also enhances the cycling experience. However, if the route goes through Khyber Pass Road-Broadway-Parnell Road, Newmarket shopping centre could also be connected.
Compared with these gaps in the inner city, the huge altitude difference between the roads on the waterfront and the roads in the inner city cannot be avoided easily by changing the route, because the altitude difference between waterfront and inner city happens on every road (see Figure 4.5).

**Strengths:**
- Creating on-road cycle paths is low-cost.
- Avoiding the gaps will enhance the cycleway’s connectivity.
- Using local paths to reach residential areas and open green spaces.

**Weaknesses:**
- Longer distances between attractions could make the cycleway a time-wasting path.
- Difficult to apply to all areas in Auckland, because of the different landscape conditions, distributions of attractions, commercial and residential areas.

Figure 4.3. Conceptual scheme1- experiment 1 (Authors own, 2017).
Figure 4.4. Conceptual scheme 1- experiment 2 (Authors own, 2017).

Figure 4.5. Conceptual scheme 1- experiment 3 (Authors own, 2017).
Conceptual scheme 2

Main strategy: using an elevated cycleway to join the gaps. Combine elevated cycleway and on-ground cycle route to make a connected cycle network.

An elevated cycleway could be independent or clip onto existing infrastructure, like the Xiamen Skyway. Considering the budget, a good choice is an independent structure for short distances and clip-on structures for long distances. Fortunately, Auckland has a well-developed motorway system and developing light rail, so the cycleway could be integrated with the existing motorway or train lines.

From Westhaven to all the surrounding areas, there are huge altitude differences, so the clip-on cycleway could go along Northern Motorway 1 and keep elevated to Quay Street, connecting with the existing cycle lane on Quay Street and go eastward to Mission Bay. As to the route from Quay Street to Newmarket shopping centre, an elevated cycleway could go above the railway. However, the connection points of the elevated cycleway and on-ground cycleway could not be built in residential areas or busy commercial areas, due to the high volume of traffic and parking requirements. Furthermore, the entrance of the elevated cycleway would need open space to avoid traffic congestion and conflict with other road users (see Figure 4.6).

If we keep the elevated cycleway from Westhaven to Dove-Myer Robinson Park along the waterfront, and connect the elevated route with the on-ground route with connection points (entrance/exit) at the right places, the cycle network would be connected and cycling traffic wouldn't disturb other road users. However, there are existing dedicated cycle lanes on Quay Street; though an elevated cycleway could provide better views of the waterfront and safety to cyclists, creating two parallel cycleways is a waste of money, and a long-distance elevated cycleway along the waterfront and in a busy commercial area may need a lot of exits, which would lead to more land use (see Figure 4.7).

The most reasonable plan is using elevated cycleways to avoid altitude difference, combining elevated cycleways with existing dedicated cycle paths and on-ground cycle lanes to create a highly connected cycle network. Although clipping onto existing infrastructure would decrease the budget of the project, building long-distance elevated cycleways still need a lot of money and may decrease accessibility of on-ground recreational area (see Figure 4.8).

Strengths:

- Solving the altitude differences with elevated infrastructure.
- Elevated cycleways lead to less land use.
- Cycling ‘in the air’ gives cyclists a better view of the city.
- Creating a better link to other areas in Auckland in the future, like the proposed bicycle plan for the Harbour Bridge SkyPath, Glen Innes to Tamaki Drive cycleway and others.
Figure 4.6. Conceptual scheme 2 - experiment 1 (Authors own, 2017).

Figure 4.7. Conceptual scheme 2 - experiment 2 (Authors own, 2017).
Weaknesses:

- Elevated infrastructure, steel material, lights and high-tech facilities may create higher costs for building and maintenance.

4.3 DESIGN SPECULATIONS

The design will focus on the cycleway along waterfront and the connections between waterfront and inner city's bicycle network (the red route in Figure 4.9), to make a model of connected bicycle network which avoid gaps made by hilly topography, other transport networks and existing infrastructure.
Figure 4.9. The concept of design (Authors own, 2017).
Analysis

Figure 4.10. Site analysis (Authors own, 2017).
A map of attractions (busy commercial areas, open green spaces and public transport stations) and the existing pedestrian and bicycle paths along the waterfront, to analyse the site and to examine possible opportunities to create an accessible bicycle infrastructure (see Figure 4.10). As we can see, Westhaven, Viaduct Basin and the commercial area around Britomart Transport Centre have a high density of human activities and a high requirement for good access to pedestrian or cycle paths. If the design connects existing cycleways in these attractions and makes the whole waterfront area an accessible and connected attraction of human activities with the bicycle network, it will not only encourage people to ride bikes but also add economic and social benefits to the CBD area.

The analysis includes on-the-spot investigations to analyse the situation of each landscape spot, following human-centred design principles. Westhaven Marina is the heart of boating in Auckland and with the construction of the Westhaven Promenade (see Figure 4.11), it is now more than ever a place that everyone can enjoy. There is a proposed bicycle skypath clipped on the east side of the Harbour Bridge and a proposed exit under the motorway (see Figure 4.12). Curran Street, near the Harbour Bridge, is a good place for people to fish, skateboard or just sit down and enjoy a good view and sunshine. However, between Curran Street and Westhaven Promenade, there is a lack of safe and accessible connection for pedestrians and cyclists (see Figure 4.13). On Curran Street, on-road car parking and cycle lane on the narrow sidewalk along the waterfront limit human activities around this area (see Figure 4.14). The big altitude difference between Point Erin Park and the waterfront provides a space under the Northern Motorway, which creates a design opportunity for landscape architects. The Northern Motorway goes over Victoria Park, making a marginal area under the motorway flyover.

The playground beside the motorway and the nice lawn make Victoria Park a busy place on weekends and a good spot to promote cycling. Silo Park already has a good landscape design on the waterfront, but the existing steel infrastructure has been barely used (see Figure 4.15). If the elevated cycleways could be integrated into the existing infrastructure, it would not only decrease the budget of the cycleway and increase the view for cyclists, but also enhance access and vitality to existing infrastructure.

The existing pedestrian-bicycle shared path from Silo Park to Britomart Transport Centre provides a good cycling experience. The continuous segregated cycle path on Quay Street becomes a painted cycle lane near Tamaki Drive and finally disappears on Tamaki Drive, where the footpath becomes a shared path for cyclists and pedestrians. However, the underground railway from Britomart Station, which is almost parallel with Quay Street, comes out above the ground close to Spark Arena, where it is spanned by a pedestrian bridge (see Figure 4.16). The railway provides an opportunity to create a cycle path that is separated from busy vehicle traffic on Quay Street and Tamaki Drive. As to the end of the cycleway, a big open green space – Dove-Myer Robinson Park – may be a good choice.

The design speculation examines possible opportunities to create an accessible and
connected bicycle infrastructure for the public, while retaining and even enhancing the existing functions in the Auckland CBD. In (see Figure 4.13) the concept of forming a connected cycleway from Westhaven Marina to Dove-Myer Robinson Park is a utilitarian solution that enables public access and enhances the safety of cycleway users by using marginal areas under motorways and above the railway.
Figure 4.17. The concept design (Authors own, 2017).
Design development

The concept design comprises four sections and six landscape nodes (see Figure 4.14) that respond to design objectives outlined in the thesis. Each section has its individual systematic programme that coexists with existing and proposed development in the Auckland CBD. The design illustrates a new independent bicycle network on the CBD waterfront that consists of vibrant social and recreational amenities surrounded by the proposed development of bicycle projects. The design principles and strategies are identified through case studies to achieve key design strategies of connectivity, accessibility and safety. Through innovative sustainable design, the concept seeks to promote sustainable mobility, attract people to ride bikes, decrease traffic congestion and implement quality public spaces.

Figure 4.18. Sections and landscape nodes (Authors own, 2017).
Section 1: Westhaven To Victoria Park

Connected with the proposed Bicycle Skyway which clipped on the east side of the Harbour Bridge, the elevated cycleway in first section has a curved bicycle off-ramp and an entrance under the Northern Motorway. The cycleway is kept elevated, across the on-ramp of Shelly Beach Rd, then clipped on Shelly Beach Rd, across the Northern Motorway and then slightly downward to connect with the existing off-road cycle path which start from Point Erin Park. The entrance square is located at the pedestrian and vehicle traffic intersection, not only connecting pedestrian traffic from both directions of Currant Street and Westhaven Promenade with a safe corridor, but also enhancing recreational space with the marginal area under the motorway. Remove on-road vehicle parking, widen sidewalk on Currant St and extend sidewalk into fishing deck, to provide more space for human activities (see Figure 4.19). Currant St is also a bike-able route in the loop of slope less than 5% which is recognised above.

The existing off-road cycle path ends at Fanshawe St and Beaumont St intersection. On-ground bicycle path could continue to Silo Park direction through Beaumont St or city centre direction through Fanshawe St which is recognised a bike-able route in the loop of slope less than 5%. Elevated cycleway is clipped on the west side of the motorway and has a curved bicycle off-ramp connects with marginal space under the motorway and to Victoria Stw and Franklin Rd direction, and a branch off-ramp connects to local path in Victoria Park and to Skate Park direction (see Figure 4.20). Franklin Rd is connected with Ponsonby shopping centre and Ponsonby Rd which is another bike-able road in the loop mentioned above.

STRENGTHS

• Removing on-road vehicle parking, extending space for human activities, filling the gaps in pedestrian and bicycle networks, enhance the connectivity, accessibility and safety of bicycle and pedestrian infrastructure on waterfront.

• Using the marginal space under the motorway decreases land use and influence on other land users.

• Elevated cycleway go through various heights, provides better cycling experience.

• Provide a bicycle ‘superhighway’ from Westhaven Marina to the central city.

• Westhaven cycleway has the opportunity that connecting Ponsonby Rd through St Marys Rd, which means enhancing the connection of bicycle network between residential area in St Marys Bay and Ponsonby shopping centre, enlarging the bicycle network’s scope of service.

• The elevated cycleway in Victoria park will not disturb recreational bicycle traffic on local paths in the park, and will connect bicycle traffic from inner city (Albert park direction), Ponsonby shopping centre, western park direction and waterfront direction (see Figure 4.21).
Figure 4.19. Westhaven entrance of the cycleway, experiment 1 (Authors own, 2017).
WEAKNESSES

- The proposed cycleway between vehicle traffic on the motorway and 5 to 10-meter high cliff obviously has worse view than the existing Westhaven Promenade along coastal edge, which has almost the same direction with the former.

- The loop connected to bicycle off-ramp may lead to unnecessary bicycle trip, and extra cost.

- An elevated cycleway above Fanshawe St and Beaumont St intersection might be unnecessary, due to there is a proposed safe intersection for cyclists and pedestrian.

Figure 4.20. Victoria Park Exit of the cycleway, experiment 1 (Authors own, 2017).
Figure 4.21. The potential connections of bicycle network around Victoria park (Authors own, 2017).
Section 2: Silo Park

Experiment

Silo Park now includes a Sunday market, playground, street park and a steel elevated platform. Silo Park's east side connects to the busy commercial area, its west side is Silo Marina and has good views of the sea, the south side is Daldy Street Park and the north side is an industrial area. The existing elevated platform cannot achieve its design purpose of offering the public a good viewing platform, due to its longer side facing the industrial area, with high buildings blocking people's view. However, the existing structure provide a good opportunity for bicycle infrastructure. However, in The Waterfront Plan 2012 (Auckland Council, 2012), Wynyard Wharf will be a large open green space when the project completed. The elevated cycleway could clip on the elevated platform and extend to the west, providing a good view of Silo Marina and Wynyard Wharf (see Figure 4.21). There is a good connection between Silo Park and the commercial area on the east – a straight and wide pedestrian-bicycle shared path. An elevated cycleway, which goes through Daldy Street Park, clipped on to the elevated platform, goes down and ends at an open space closes to the open-air cinema, and can offer shelter for people in the street park, enhance the function of the existing platform, and connect with the on-ground network.

STRENGTHS

- The cycleway clipped on the existing structure connects with existing mixed-use development, while providing quick access to open space to cyclists.

- The design is separated from on-ground road network and recreational area, decrease the conflicts between cyclists and other land users.

- The design starts a straight bicycle route along waterfront from Silo Park to Quay St, enhance the accessibility and connectivity to bicycle network.

WEAKNESSES

- The route of the elevated cycleway could be alternated by bicycle-pedestrian shared path in street park with much less budget.

Figure 4.21. The waterfront plan 2012 (Auckland Council, 2012).
Figure 4.22. Silo Park exit, experiment (Authors own, 2017).
Section 3: Quay St Cycleway

Experiment 1

There is already a pedestrian bridge over the railway and a two-way cycle path on the other side of the street. The railway goes slightly up, from under-ground at the Britomart Transport Centre to on-ground at the eastern train line. There is an opportunity to connect the bicycle network on Beach Rd and the cycleway on Quay Street with creating cycle lanes on Mahuhu Crescent and Tapora Street. However, it is hard for cyclists crossing six-lane traffic on Quay St to reach the existing cycleway. The bicycle on-ramp of elevated-cycleway in experiment 1 is proposed to connect Tapora Street and keep elevated over railway. Connecting the elevated cycleway with the existing pedestrian bridge and diverting the on-road cycle lane into an independent cycle route over the railway can decrease conflicts between vehicle drivers, cyclists and pedestrians, increase the connectivity of the bicycle network, and create a new connection between the bicycle traffic on Quay Street and Beach Road.

When the cycleway comes to the bridge above the railway, in order to bypass the narrow space under the bridge, the cycleway goes through north side of the bridge, which has no railway underneath. The traffic on the ground will not affect the project. When deciding the height of the cycleway over the train line and under the bridge, it is necessary to consider the gradients and curve.

STRENGTHS

• Linking Quay Street to Beach Rd with bicycle network through low-traffic volume street enhances the connectivity of bicycle network.

• An independent cycleway over railway decreases the conflicts between cyclists and other road users and create a dedicated cycle path provides cyclists relatively shorter time than ones on-road cycle lane to get destinations.

WEAKNESSES

• Re-building the existing concrete pedestrian bridge makes extra budget of the project.

• The bicycle on-ramp starts at on-road cycle path adds barrier to on-ground bicycle traffic.

• Elevating the cycleway above railway may costs a lot of money.

• Compared with bypassing the space under the bridge, connecting with bicycle network on the bridge might have better connection with bicycle network on The Strand and Parnell’s residential area.
Figure 4.23. Section 3, experiment 1 (Authors own, 2017).
Experiment 2

The elevated cycleway is created to connect bicycle network on Quay St and The Strand with the Strand train station. Creating the cycleway starts from Te Taou Res to Dove-Myer Robinson Park provides direct connection between open green spaces and train station. Te Taou Res as a good open green space near residential area, now is surrounded car parking place which keeps people away from it, so the design removes car parking and extend public space to connect with Beach Rd. Leave the pedestrian bridge and plaza in front of Spark Arena intact, and make connection through Tangihua St and Tamaki Dr bridge (see Figure 4.24).

STRENGTHS

• Creating and enhancing connections between on-ground bicycle network through low-traffic volume street, on-ground bicycle network and elevated bicycle network through elevated connection, and bicycle network and transport station.

• Strengthening the accessibility of open green space and transport station.

WEAKNESSES

• Increase budget.
Figure 4.24. Section 3, experiment 2 (Authors own, 2017).
Section 4: Dove-Myer Robinson Park Cycleway

Experiment 1

Dove-Myer Robinson Park is on the south side of Tamaki Drive. Beside Dove-Myer Robinson Park is a car park and open green space. However, Dove-Myer Robinson Park has a 23-metre altitude difference with the train line (see Figure 4.24). Such a big altitude difference needs at least a 500-metre bicycle off-ramp, which is not only a waste of money but also makes a long-distance, meaningless cycle trip. Compared with test exit A, test exit B is a better choice, because the largest altitude difference between the train line and the cycleway will be about five metres, and the off-ramp should be around 250 metres, which is an acceptable distance for cyclists (see Figure 4.25).

STRENGTHS

- Create connection between bicycle network on Gladstone Rd and Tamaki Dr, decrease barriers in bicycle network.
- The cycleway accesses to open green space and residential area, increases social and recreational value.

WEAKNESSES

- Lack of good view of the environment and enjoyable cycling experience.
- The design of bicycle off-ramp creates at least 250-meter cycling trip which is lack of enjoyable cycling experience and doesn't avoid big gradient on Glandstone Rd.

Figure 4.25. Observation through Cross-section of the site (Authors own, 2017).
Experiment 2

On one hand, the elevated cycleway clips on the edge of Dove-Myer Robinson Park turns into a recreational cycleway along the water. The cycleway goes into the park along contours and connect to bicycle network on Glandstone Rd. A coastal promenade is created along Judges Bay Road, ends at Parnell Baths. On the other hand, the elevated cycleway goes slightly down to the ground and keep going to Outboard Club direction on the side of the railway (see Figure 4.27).

STRENGTHS

- Enhance recreational use of the cycleway.
- Provide potential of cycleway that connecting further area.
- Vary the cycling experience on the cycleway.

WEAKNESSES

- Complex changes of altitude differences increase difficulty of construction.
Figure 4.27. Section 4, experiment 2 (Authors own, 2017).
**Phased Implementation**

The initial design strategy involved mapping out open attractions, such as open green spaces, shopping centres, transport stations, and creating new pedestrian and bicycle connections between and inside attractions. These interventions were proposed to be implemented at different stages in order to revitalize the site and its surroundings as a long term phased plan approach. The following diagram explains what intervention involves, and the outcome expected from each intervention.

1. On-road cycle lanes connects central city and surrounding areas, provides slow-speed cyclepaths between attractions for recreational use (see Figure 4.28).

2. Elevated-cycleway connects central city and further surroundings, such as Harbour bridge and Orakei Bay, while avoiding barriers of topography and connecting train station, providing fast-speed cycleways between downtown and further surroundings (see Figure 4.29).

3. Coastal promenade in Westhaven and Judges Bay. This is proposed to enhance waterfront’s recreational use. Westhaven promenade also supports access from Westhaven to Silo park (see Figure 4.30).

4. Coastal pedestrian and cyclepath from Silo park to Tamaki Dr. This is proposed to enhance bicycle and pedestrian’s accessibility in waterfront, and connect cycleway on Tamadi Dr, making a further connection between Mission Bay and central city (see Figure 4.31).

5. Pedestrian and cyclepath in open green spaces, one goes through Daly Street Park to Silo park which eventually connects Westhaven promenade, Victoria park cycleway and Wynyard crossing, the other one goes into Dove-Myer Robinson Park and connect elevated cycleway and on-road cycleway, enhance bicycle network’s connectivity (see Figure 4.32).

6. Connections fill gaps in bicycle network with low-traffic volume roads (see Figure 4.33).

7. Bicycle playgrounds and plazas support bicycle network’s recreational use and provide public spaces to connect open green space and bicycle network (see Figure 4.34).
Figure 4.28. On-road cycle lane around city centre (Authors own, 2017).

Figure 4.29. Elevated cycleway connects city centre and further surroundings (Authors own, 2017).
Figure 4.30. Coastal promenade enhance recreational use of bicycle path (Authors own, 2017).

Figure 4.31. Cycle path along waterfront (Authors own, 2017).
Figure 4.32. Cycle path in green open spaces (Authors own, 2017).

Figure 4.33. Connections fill gaps in bicycle network (Authors own, 2017).
4.4 SUMMARY OF DESIGN

The design chapter of the thesis tests multiple opportunities and constraints in the Auckland CBD, through strategic integration of existing and potential urban development. The proposed designs are rationalised from comparative design strategies, principles and findings extracted from the literature review.

Initial tests of the site explored potential design opportunities and constraints in the CBD, which reflected a hybrid use of design principles and strategies. Through critiquing these preliminary tests, the design site is narrowed down to a specific area in the CBD. A thorough analysis of the CBD region and traffic was initiated to resolve Auckland’s urban mobility challenges via sustainable and innovative initiatives. The design speculation led to ambitious yet pragmatic design moves to provide connectivity, accessibility and safety for urban bicycle infrastructure.

The design development phase encompassed four sections, each having its separate
functions that mediate through an integrated system along the cycle network. Multiple design strategies lead to major design interventions that supported a retained bicycle network development, thus identifying areas for improving connectivity, accessibility and safety. Following the design development phase, some opportunities and constraints were rationalised through design by research and will be critical in shaping the final design proposal.

**Opportunities**

- To develop a vibrant and a multi-functional public space along the bicycle network by using marginal area around an existing transport corridor.

- An independent cycle network, which is separated from, but attached to, the existing transport infrastructure to enhance the transport corridor’s aesthetic value, encourage human-powered transport, expand entertainment zones, while connecting the entire Auckland waterfront and commercial and recreational zones around waterfront.

- To decrease the influence of topography on human-powered transport, and enhance the connection between the waterfront and the inner city.

- Constructing an efficient bicycle and pedestrian route for recreation and commuting away from high-volume traffic routes, can not only increase the safety of human-powered transport, but also decrease the congestion of vehicles while having no negative effect on the traffic volumes on roads.

**Constraints**

- Building an entrance/exit square in an existing public space may create congestion of people on weekends or days of big events.

- The distance required between electrical wires and the steel cycleway, to protect cycleway users and avoid affecting the operation of the train system, leads to extra height of the elevated cycleway and less anti-wind capability, which may require more money to reinforce the cycleway.
5.0 DESIGN PROPOSAL

Overview

Masterplan

Sections

Perspectives

Design summary
5.1 OVERVIEW
The final design proposal is derived from a criterion consisting of design principles and strategies from the literature review and case studies. The development of the proposed outcome is manifested within the speculative design process. This proposal identifies the Auckland bicycle network's key issues that will have major impacts on Auckland region, in particular, the Auckland CBD.

This thesis rationalises the integration and separation of different transport systems, to enhance urban mobility through improving the connectivity, accessibility and safety of cycling infrastructure. The core objective is connecting open green spaces, commercial areas and transport stations with an independent bicycle network. This objective is accomplished by creating cycleways that clipped onto the motorway and elevated over the railway, redeveloping marginal areas near the transport corridor as recreational areas, and connecting the proposed bicycle route with the existing route. These interventions enhance the connection of attractions in the entire waterfront and encourage recreational human activities, especially cycling in the CBD area. This proposal is a solution and a model that can act as a catalyst for the entire Auckland bicycle network.

The design as a whole is categorised into four sections which exemplify the site-specific character and functional purpose within the existing urban conditions.

The cycleway uses the same colour – magenta – as the Nelson Street Lightpath to give people a vibrant feeling. The five-metre width provides enough space for pedestrians and cyclists, and people who use the cycleway to enjoy good views. The main part of the project starts from Westhaven Marina and ends at Parnell Baths, the total length is six kilometres, it connects seven open green spaces, five plazas and the waterfront. To match the future requirement of bicycle parking, the five-metre cycleway has the potential to be turned into a half cycling, half parking path in some sections, as in the case study of the Xiamen Cycleway.

5.2 Masterplan
Figure 5.1: Design proposal-Masterplan (Authors own, 2017)
Figure 5.2: Design proposal summary (Authors own, 2017)
5.3 Sections

Cross-section A-A’

Before

After

Figure 5.3. Cross-sections of Westhaven cycleway off-ramp (Authors own, 2017).
Figure 5.4. Victoria park cycleway off-ramp (Authors own, 2017).

Figure 5.5. Cycleway under the bridge (Authors own, 2017).
Cross-section D-D’

Before

After

Figure 5.6. Cycleway above train station (Authors own, 2017).

Cross-section E-E’

Before

After

Figure 5.7. Costal Promenade close to Parnell Baths (Authors own, 2017).
5.4 Perspectives

Figure 5.8. Masterplan and viewpoints (Authors own, 2017).

Figure 5.9. Westhaven cycleway exit (Authors own, 2017).
Figure 5.10. Westhaven cycleway off-ramp (Authors own, 2017).

Figure 5.11. Victoria park cycleway off-ramp and exit (Authors own, 2017).
Figure 5.12. Victoria park cycleway exit and surroundings (Authors own, 2017).

Figure 5.13. Cycleway under the Strand Bridge (Authors own, 2017).
Figure 5.14. Curved cycleway under the Strand Bridge (Authors own, 2017).

Figure 5.15. Cycleway above the Strand train station (Authors own, 2017).
Figure 5.16. Public plaza with bicycle parking and playing place close to Te Taou Res (Authors own, 2017).
5.5 DESIGN SUMMARY

The research by design process explored critical relationships between Auckland’s urban mobility and its bicycle infrastructure conditions at different scales. A combination of literature review, site analysis and design speculation derived criteria and set design principles, outlining opportunities and constraints. The proposed outcome was responsive towards the design objectives while articulating critical design strategies, which include connectivity, accessibility, safety and sustainability. An iterative process during the design speculation phase established common threads as well as identified areas of conflict. Design development analysed the conditions of each specific area and illustrated the practical application of design principles within landscape nodes. The final proposal is the result of this empirical process in response to Auckland’s contemporary challenges of mobility.

The proposed design is influenced heavily by Jan Gehl’s Human-centred Urbanism, case studies of bicycle infrastructure, and the Auckland Council’s bicycle planning for the future. Auckland’s critical challenges are addressed throughout the entirety of the project, which are embedded in the new framework. The proposal is designed towards achieving a synergy between existing and proposed urban transport development at a human scale. A strategic integration of diverse multiple programmes proposed within the existing urban transport network enhances connectivity, accessibility, safety, vibrancy, identity and place attachment.

This model is a pragmatic and a comprehensive solution towards Auckland’s bicycle network development. It is an incentive for Auckland’s bicycle network development at various scales that deal with similar challenges and scope for injecting connected, accessible and safe bicycle infrastructure.

STRENGTHS

- Resolving critical issues of Auckland’s mobility through a creative and comprehensive bicycle network that is responsive to existing and future challenges. A separation of existing network that explores the opportunities of creating an independent cycle network which can provide excellent synergy with existing infrastructure while clearly separating use.

- An integrative approach that fits into current and proposed development of bicycle infrastructure while strengthening the synergy between waterfront and city.

- The design can be progressively staged due to the limitations of Auckland’s economic expenditure and to observe the public’s involvement over time.
WEAKNESSES

- Despite the independent cycle network avoids the conflict between bikes and vehicles, cyclists’ safety on intersections are hardly to be guaranteed due to complex traffic conditions and diverse styles of intersections.

- With the rise of cyclists using bicycle network, the requirement of bicycle parking place will increase. Although the proposal suggests that adding bicycle parking on certain parts of the cycleway, a design of bicycle parking facility which can store more bicycles or integrate with bicycle sharing systems is necessary.
6.0 CONCLUSION
Research question

Can an independent cycle network to make bicycle use a primary form of transportation, to provide sustainable mobility for Auckland?

A relationship between the rising consumption of fossil fuels and reducing quality of urban environments is now generally accepted. The biggest culprits of urban pollution are combustion-driven vehicles. As a result, interest is growing in viable ‘green’ alternatives to city mobility. Among electric vehicles, electric bikes and bicycles, the top consideration is the common bicycle, which has been regaining popularity in modern cities as a simple, inexpensive, low-impact and localised solution to moving within cities. In the case of Auckland, a strong outdoor culture rarely includes cycling in the many definable ‘kiwi’ outdoor activities. Reasons given for this include the problems of geography and infrastructure. However, the popularity of outdoor activities and high density of recreational areas offer big opportunities for development of bicycle infrastructure. In addition, Auckland Council has promised investment of $300m over the next 10 years and already developed several cycleways around city centre. However, the current programmes deal inadequately with safety, aesthetics and expense.

This thesis consolidates pertinent information from the literature review, which includes theories, design principles and case studies, which explore design principles and strategies. Through comparing three popular city plannings, Jan Gehl’s Human-centred Urbanism which emphasizes the relationship between human activities and city planning is considered a practical theory for sustainable urban planning. In addition, because most of Gehl’s work, such as Copenhagen’s city centres, Melbourne’s city centre redevelopment (Gehl & Gemzoe, 1996), and London’s ‘cycle superhighway’ plans (Bramley, 2014), has focused on the bicycle to make citizens can easily travel in cities without individual cars (Bramley, 2014), Jan Gehl’s philosophy has been proved to be a suitable theory for the development of bicycle infrastructure in modern cities. Moreover, three case studies: Copenhagen’s Bicycle Snake, Xiamen’s Bicycle Skyway and Auckland’s Bicycle Lightpath, represent new models of urban cycleway with different materials, surfaces and structures from traditional bicycle path. The study of previous projects gives an idea that using elevated cycleway to avoid the barrier of topography and relieve the conflict between bicycles and vehicles.

According to context analysis, landscape analysis and experiential analysis, the research shows that the bicycle network in the Auckland CBD is still disconnected after many bicycle facilities have been built. On the other hand, the analysis has proved that the bicycle network in the CBD has a good potential to encourage people to ride bikes if designers could improve accessibility and connectivity of bicycle network to open spaces, the waterfront and commercial areas.

Through GIS mapping, data collection and calculation, site investigation to analyse site, the final design proposes a connected bicycle network to resolve Auckland’s urban mobility challenges. The design encompasses four sections: (1) Westhaven to Victoria park; (2) Victoria park to Silo park; (3) Silo park to Quay St (4) Beach Rd to Parnell.
Baths, each having its separate functions that mediate through an integrated system along the cycle network. Multiple design strategies lead to major design interventions that support existing transport network and connect open green spaces and transport stations, thus identifying most reasonable concept for improving connectivity, accessibility and safety.

This project suggests a separation of existing networks, and explores the opportunities of designing an independent cycle network that would provide excellent synergy with existing infrastructure while clearly separating use – for the safety and benefit of cyclists, motorists and pedestrians. It is expected that such a cycle network would encourage cycle use as a primary form of transportation, making Auckland a greener, safer, more enjoyable and less expensive place to live. The proposal can also be conceptualised in stages that provide a fundamental structure to shape the following steps in a progressive manner.

It would be beneficial to continue this research. There appears to be increasing interest in developing bicycle infrastructure in modern cities. Further investigation and research in the later stages can target the supporting facilities of cycle networks, such as bike-sharing systems and bicycle parking, and the integration of the bicycle network and the public transport system.
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