WHAT IS THE FUTURE OF STORMWATER MANAGEMENT FOR TRANSPORT AND URBAN ENVIRONMENTS IN NEW ZEALAND?

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ABSTRACT

New Zealand’s response to stormwater management for our transport and urban environments will change in the future but how? This paper considers the future drivers due to population growth, changing transport choices, technology, environment, climate change and government policy drivers. By considering these drivers we can better plan, design and manage our stormwater infrastructure and invest well for the future.

Our transport systems are changing significantly due to population growth, uptake of electric vehicles (EVs) and modal shifts to walking, cycling and public transport.

Technology will also change mobility through personal transport devices, EVs and autonomous vehicles, as well as how we potentially manage stormwater quality by source control measures for brakes or new treatment and maintenance technologies.

The environment is also changing due to factors such as climate change. Meanwhile, the cumulative impacts of our activities on the environment are being felt strongly and a stronger stormwater management response is likely to be required.

The current government policies are known and New Zealand’s commitments through international agreements to climate change and sustainability are clear, so we can begin to anticipate the consequential requirements.

The stormwater infrastructure we are building is normally designed for a 100 year life so we need to consider the foreseeable changes that will occur during the life of the assets. We need to future-proof the stormwater infrastructure we are building today to avoid regretful/wasteful spending on redundant infrastructure or future expensive retrofit.

In this paper we explore each of these drivers for change, considering their impact on stormwater management for our transport and urban environments, including the timing. We advise on where changes will be impactful, their timing, and what stormwater managers, planners and designers should be considering at present to be future-proof or at least future-aware.

KEYWORDS

Stormwater management, future, electric vehicles, water quality, climate change, policy, technology

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1 INTRODUCTION

New Zealand's transport environment is changing. The future way in which New Zealander's travel to work, school, university, across town, or to the local shopping mall will look different from now.

Current urban stormwater quality and quantity management is heavily influenced by the spatial scale and use of transport infrastructure – in particular, public road infrastructure to facilitate the use of private and commercial vehicles. At present, vehicles are a key source of heavy-metal and hydrocarbon contaminants in stormwater runoff. Similarly, the impervious areas of roads and footpaths generate greater flowrates and volumes of stormwater runoff than natural, pervious areas which allow for infiltration. Therefore, stormwater quality management depends on the composition of transport infrastructure, which in turn is dependent on New Zealanders' transport preferences. These preference are influenced by numerous regulatory, social, technological, environmental and economic drivers.

Planning for future stormwater infrastructure must take into account these drivers to ensure that stormwater infrastructure will be sufficient to meet its functional requirements over the required design life – which in New Zealand, local and national authorities typically specify as 50 to 100 years for public infrastructure. The investment in stormwater infrastructure is large and assets indicatively have a 100 year life, so it is important that the investment is efficient and future-proof. For local government alone the stormwater assets are valued at $11.2 billion (The Treasury - National Infrastructure Unit, 2015), and the 10 year (2016 – 2025) capital intentions are worth $2.2 billion (The Treasury - National Infrastructure Unit, 2016).

To date, limited research has been done on exploring how future changes to New Zealand's transport and urban environments will affect the management of stormwater quality and quantity. In the present study, a high-level analysis was conducted as a starting point to identify and discuss the key drivers which practitioners and policy makers should consider in their decision-making on stormwater management.

1.1 PREVIOUS INSIGHTS INTO NEW ZEALAND'S TRANSPORT FUTURE

In 2017, the Ministry of Transport released a comprehensive, scenario-based study on New Zealand's possible future transport sector (Ministry of Transport, 2017b). The study, *Transport Outlook: Future State* (TOFS), provides an insight into what New Zealander's transport habits may look like in 2042/43. This is useful when considering transport's effects on future stormwater quantity and quality.

TOFS draws heavily from the 2013 Census data to project future transport statistics. Varying model projections were grouped into five different future scenarios, which are summarised as follows:

Base Case – The base case scenario assumed the New Zealand economy and population would grow at a medium rate, with a focus on Auckland, Waikato and Bay of Plenty regions. It also assumed that 20% of current private vehicle usage would transfer to vehicle-sharing, and that 40% of the vehicle fleet would be electric by 2039/40. Technology changes were assumed slow and non-disruptive.

Staying close to the action – this scenario assumed that New Zealand will experience medium growth in population and economy. In addition, that 40% of present-day private vehicle trips will shift to vehicle-sharing, and that public transport, ride-sharing and cycling will also become popular. People were also assumed to be centrally located, and that Auckland and Wellington would adopt a pricing scheme for demand management.

Metro-connected – medium urban population and economic growth was also assumed for this scenario, as was a 40% shift in private vehicle usage to vehicle-sharing. A key difference was that this scenario assumed technology improvements would allow businesses to better disperse their operations throughout the country. Also, that online shopping and freight tonnage would increase nationally.

Home in town and country – this scenario assumed many New Zealander's would be highly flexible in their work location, with working from home becoming normal. It also assumed a rapid growth in economy and population. With people preferring to communicate through information technology, it was assumed many people would go without a car, where 80% of current private vehicle trips would transfer to vehicle-sharing.

The golden triangle – for this scenario, rapid growth in population and economy was assumed, with a focus on the Auckland-Waikato-Bay of Plenty regions. As a result, suburbs would sprawl and freight tonnage would increase. Private vehicles would tend to be self-driving, and total car ownership would fall with an increase in vehicle sharing (60% of current private vehicle trips).

An important limitation of TOFS is that it didn't include any provision for the effects of climate change on transport infrastructure. The effects of climate change, in a New Zealand context, are the topics of ongoing research. To date, research has ranged from prediction of changes in climate behaviour (Stocker *et al.*, 2013; Carey-smith, Henderson and Singh, 2018; Ministry for the Environment, 2018) to guidance for local governments on how to assess impact of the effects (Mullan *et al.*, 2008; Simonson and Hall, 2019).

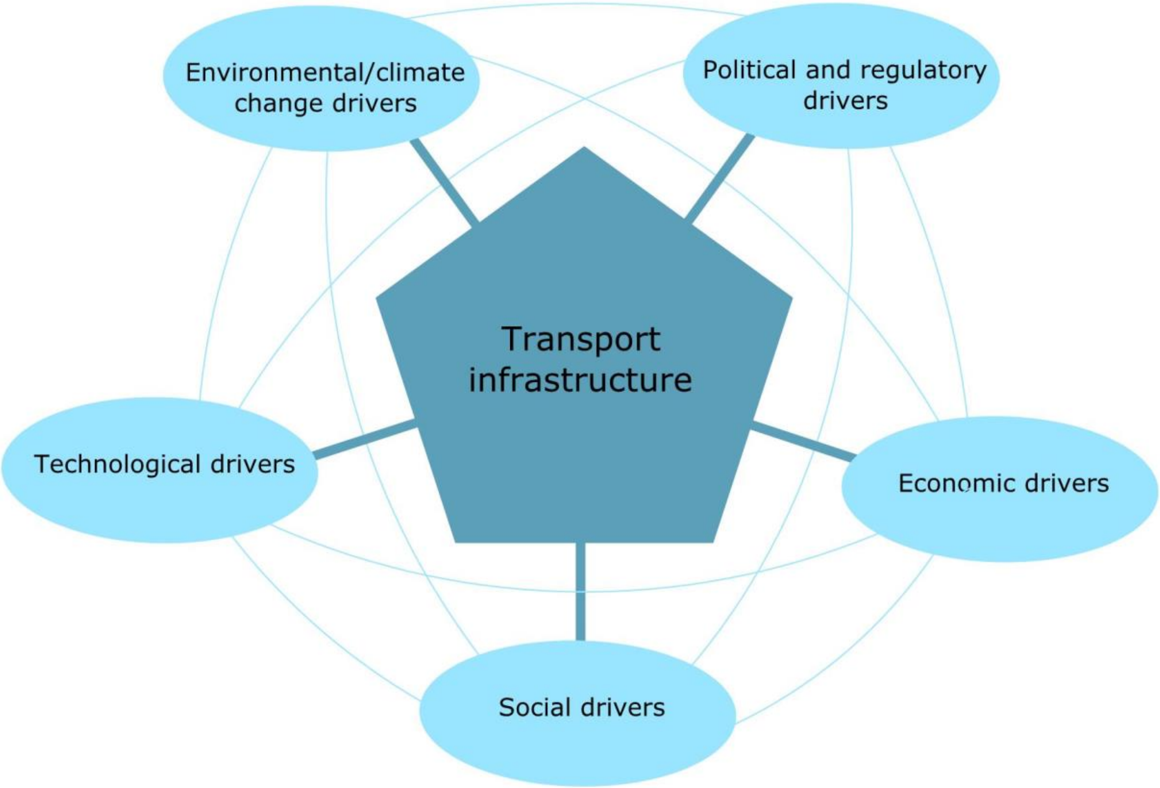
Other insights into New Zealand's transport future include industry outlook reports, such as Transpower New Zealand Ltd.'s recently commissioned report on New Zealand's future energy supply/demand scenarios (Transpower New Zealand Ltd, 2018), and Engineering New Zealand's *Engineering a better New Zealand* series – the second edition which focuses on future clean energy and clean transport (Engineering New Zealand, 2018).

2 METHODOLOGY

To predict what effects the future transport environment will have on stormwater management, drivers for change in transport infrastructure and travel preferences must first be identified. For this study, a PESTEL framework was adopted to categorise the drivers and encourage thinking across the different categories.

PESTEL analysis is a common business analysis tool used to assess macro-environmental influences on an organizations performance. PESTEL (a mnemonic for Political, Economic, Social, Technological, Environmental and Legal drivers) framework has also been used to identify drivers affecting transport technology and policy (Docherty and Shaw, 2011; Leviäkangas, 2016; Månsson, 2016). An adaptation of the framework was adopted for the present study, considering the following driver categories: political/regulatory, economic, social, technological and environmental/climate change (Figure 1).

Figure 1: Categories of drivers adapted from PESTEL that are considered to influence stormwater management in urban New Zealand. Many drivers are co-dependent/influenced by drivers from different categories



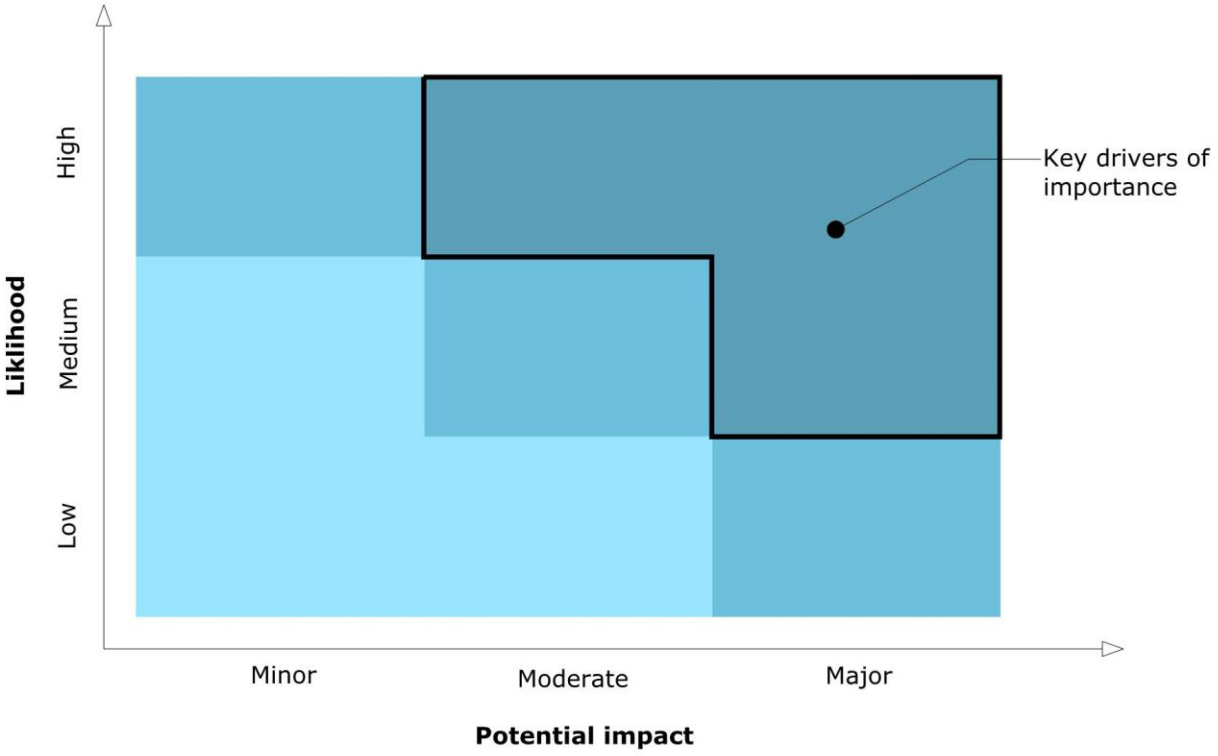
A literature review was undertaken to identify the key drivers in each PESTEL category (for a comprehensive list, refer to the appendix). Each driver was investigated to ultimately determine its importance towards stormwater quality and quantity management.

Firstly, the impact of each driver on transportation systems was considered because of the importance of the transportation systems to stormwater management. The impacts on transportation systems ranged from the direct physical impact of climate change on transport infrastructure, to the indirect impact of changing social preferences on vehicle usage. The likelihood of the driver occurring was then considered, followed by the expected environmental implications, should it occur.

The implications of each driver and their impact on stormwater quality and quantity was then investigated. These impacts were categorised as either positive or negative, with a weighting of minor, moderate or major. For stormwater quality, the impact was considered positive if it will improve runoff quality (reduction in contaminants), or reduce the need for water quality treatment. For stormwater quantity, the impact was considered positive if it will cause a reduction in peak runoff flowrates/volumes, or improve infrastructure resilience/adaptability towards the future climate.

The key drivers of importance were identified by comparing the drivers' potential impact, with the likelihood of their occurrence, as shown in Figure 2.

Figure 2: Driver importance matrix. The likelihood of driver occurring is considered against the driver's potential impact on stormwater quality and quantity to obtain the driver's overall importance towards future stormwater management

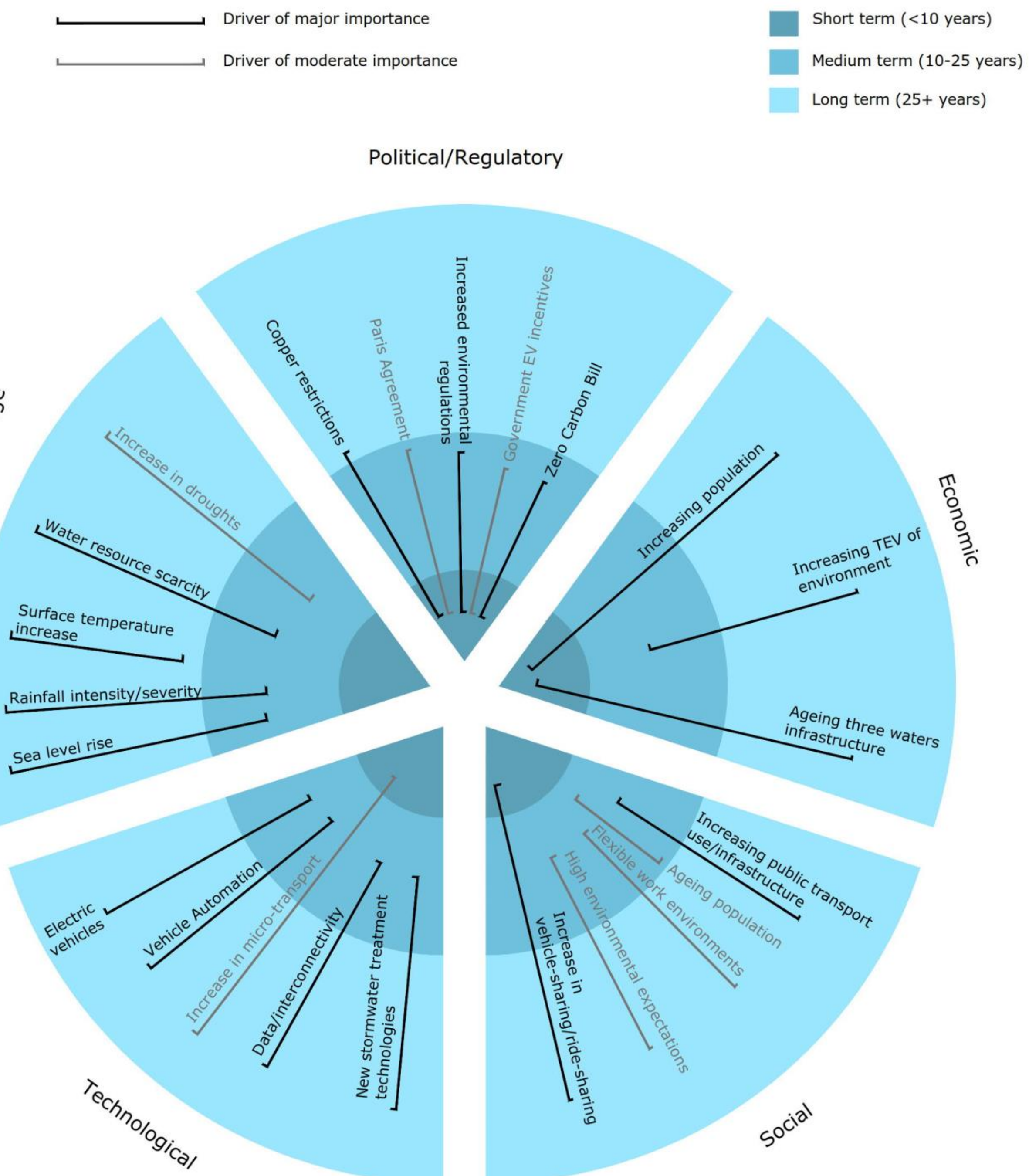


To understand the collective impacts of the drivers it is important to recognise the time frame over which they occur. Timeframes of each driver were identified over a range of short, medium and long term. For the present study, short term was defined as less than 10 years, medium term 10 to less than 25 years, and long term greater than 25 years. This range was chosen to align with TOFS, allowing compatible data projections.

3 THE DRIVERS FOR CHANGE

The key drivers of importance and their timeframes are shown in Figure 3.

Figure 3: Identified drivers of moderate and high importance, plotted for each driver category. Indicative timeframe for each driver is shown



3.1 POLITICAL AND REGULATORY DRIVERS

Copper is a common heavy metal contaminant in stormwater runoff from trafficked pavements. Within the Auckland CBD catchment load, it is estimated that 63-83 g/year of copper arises from brake pads emissions (Kennedy and Sutherland, 2008). Copper can be detrimental to ecosystems and human health (Straffelini *et al.*, 2015). The heavy metal is used as an ingredient in the brake pads to improve performance. Overseas state authorities have recently imposed regulations around allowable copper content – California and Washington State both passed bills in 2010 to limit the copper content of brake pads to 0.5% by weight (*SB346 Hazardous materials: motor vehicle brake friction materials*, 2010; *RCW 70.285.030 Prohibition on the sale of certain brake friction material—Exemptions*, 2010). New Zealand is yet to legislate any national or regional restrictions on copper content in brake pads, however with the improvements in alternative additives, such as rock fibers and thermo-graphite (Aranganathan and Bijwe, 2016), it is considered likely a restriction will be introduced in the short to medium-term.

New Zealand is increasingly enforcing stricter, more comprehensive national and regional environmental regulations around water management. There is also growing cultural awareness – from both a legal and social perspective – of kaitiakitanga (guardianship) of waterways through engagement with local mana whenua (Māori iwi/tribes who have territorial or historic rights to the land). For example, the recently revised 2017 National Policy Statement for Freshwater Management, which outlines the objectives and policies for freshwater management under the Resource Management Act 1991, will improve stormwater runoff quality and enforce additional protection to receiving environments. In Auckland, this is initially realised through the Auckland Unitary Plan, and subsequently GD01/GD04/GD05, which have an emphasis on water-sensitive stormwater design. The impact will be more mitigation of water quality impacts through source management and treatment.

As a signatory of the Paris Agreement, New Zealand’s National Determined Contribution (NDC) is reducing carbon emissions below 2005 levels by 2030.To date, the government has not provided any direct regulations or commentary on the reduction of vehicle emissions to meet the Agreement targets. However, the government has proposed the Zero Carbon Bill, which has a key policy of reaching net zero carbon emissions by 2050, as well as supporting global climate action. It is likely in the short to medium term that once the Bill has been passed into legislature that present or future governments will provide more direct objectives for vehicle emissions. This may incorporate incentives for EV uptake, contributing to the reduction in hydro-carbon contaminants in stormwater runoff.

There are many other political and regulatory drivers which have an unknown effect on future stormwater management, due to the lack of policy, or policy detail. This is not limited to the Three Water Reform, Regulation 2025 (review of the potential impact of technology on the transport systems) and measures for climate change resilience.

3.2 ECONOMIC DRIVERS

One of the most important drivers which influences future transport infrastructure development and decisions is population growth. The median projected population of New Zealand is expected to rise to 5.9 million by 2043, with a 95th percentile projection of up to 6.58 million (MacPherson, 2018). Under the TOFS Base Case, it is expected that population increase will primarily be within the ‘golden triangle’ of Auckland-Waikato-Bay of plenty regions. The increasing population of urban centres will continue to drive the need for additional transport infrastructure – including roading for private/commercial vehicles and public transport needs, heavy rail/light rail for commercial/public transport needs, and shared-use paths for pedestrian, cycling and micro-transport use. Coupled with housing requirements, urban centres will densify, resulting in an increase in impervious areas. Depending on other regulatory, technological and social drivers (such as development restrictions), it is likely that this will result in increased runoff and contaminant loads.

New Zealander's are shopping online more, with total online spending in January 2019 estimated at a 9% increase from the previous year (Bank of New Zealand, 2019). It is expected that online spending will continue to rise, resulting in an increase in freight services, and a potential decrease in private trips due to people choosing to shop online, rather than in-person. However, it is expected that the net increase in freight will only be minor (Ministry of Transport, 2017b). Therefore it is expected to have little impact on future stormwater quality and quantity.

The total economic value (TEV) of the environment is becoming an important factor in both commercial and social settings – New Zealander's are increasingly valuing their access to, and conservation of, the environment. TEV includes the value of indirect use (e.g. the biodiversity in a stream) as well as direct use (e.g. water for irrigation). As a result, we will likely include the economic value of the environment in decision making to a great extent in the future. The use of TEV will also lead to stormwater management practices that achieve outcomes other than stormwater treatment such as aesthetic and ecological. Therefore, stormwater treatment devices such as wetlands, raingardens and bioretention swales are likely to become a preferred treatment option in both private and public infrastructure developments.

New Zealand's ageing stormwater infrastructure poses an ongoing financial threat and safety hazard to local governments. This is heightened when considering increased runoff flowrates from future densification, and the detrimental impacts of climate change (see Section 3.5). As an example, Auckland Council has $4 billion of stormwater assets current depreciation of $45 million/year, which gives an indication of the size of the burden to maintain that stormwater system (Auckland Council, 2015).

3.3 SOCIAL DRIVERS

Urban public transport use in New Zealand continues to increase. In Auckland, trips have increased from 25.3 million in 2005 to 52.5 million in 2018 (AT Metro, 2019). There are numerous drivers leading to this increase – growing population, the costs associated with private vehicle usage no longer being economically viable for some people, environmental awareness, improved ranges of available services and real-time information, and the growing increase in travel time/inconvenience caused by congestion.

The New Zealand population is ageing and there is an increasing need for services with accessibility for elderly patrons. The percentage of the population aged 65+ is expected to increase to 26% by 2063, from 14% in 2013 (MacPherson, 2018). MacPherson (2018) notes this is due to a combination of people having fewer children, life expectancy increasing and the ageing of a large number of people born between 1950 and 1970. Meanwhile young adults are more likely to use public transport (Ministry of Transport, 2017b).

The number of cycle-trips and associated infrastructure is increasing within urban centres due to the increasing cost and trip times associated with private vehicle transport, paired with New Zealanders' growing social acceptance of active transport modes. Data from 26 counters across urban Auckland showed that cycle trips in the year March 2018 to February 2019 increased 20% from the previous 12 month period (Auckland Transport, 2019).

The demand for public transport, active transport, personal micro-transport, and pedestrian infrastructure in the short to medium term will continue to increase. This is likely to have numerous positive impacts on stormwater quality and quantity. Firstly, a shift from private to public transport/micro-transport will reduce contaminants associated with private vehicles in stormwater runoff. This will also take pressure off key arterial routes, and reduce the need to increase impervious areas on roads – resulting in less increase in stormwater quantity. We expect a re-allocation of the transport corridors away from private vehicles (traffic lanes and car parking) to public transport/micro-transport. Additional infrastructure will be needed to support the demand in services, which provides opportunities to include water sensitive solutions to reduce peak stormwater runoff flowrates.

Vehicle-sharing and ride sharing are also expected to increase in use, as technology improves and convenience increases, as well as the cost of parking/storing vehicles in city centres. Combined with a shift towards public transport, and increasing value of land within city centres, it is likely that public/private carparks will reduce in size or be replaced as they become redundant. This will reduce contaminated runoff from carparks requiring treatment.

3.4 TECHNOLOGICAL DRIVERS

Throughout history, technological advancements in transportation have had a significant disruption to the way people choose to travel. The invention of the steam-powered locomotive in the early 1800s to mass production of hydrocarbon-powered personal vehicles a century later have both heavily contributed towards the accessibility and development of modern urban and rural centres. In recent years, urban transport modes have become more complex and varied, with ride-sharing and electric-powered mobility devices just some of the technologies emerging as alternative options to traditional public and private transport modes. Projecting the uptake of these new technologies and trends gives insight into how New Zealand's transport infrastructure may change, and the subsequent effect on stormwater quality and quantity management.

3.4.1 ELECTRIC VEHICLES

The uptake of electric vehicles (EVs) in New Zealand has increased rapidly in the last five years. Although the current national fleet is estimated at approximately 6500 vehicles (Ministry of Transport, 2017a), by 2050 EVs are projected to hold an 85 per cent market share in New Zealand's vehicle fleet (Transpower New Zealand Ltd, 2018). Understandably, EVs provide environmental benefits over their hydrocarbon counterparts; not least, total lifecycle emissions are considered to be half that of the latter (Nealer, Reichmuth and Anair, 2015). From a stormwater quality perspective, the increase in electric vehicle market share will invariably cause hydrocarbon concentrations within stormwater runoff to decrease. However, there are expected to be no direct implications of EV uptake on stormwater quantity.

3.4.2 VEHICLE AUTOMATION AND SMART SYSTEMS

Improvements in vehicle smart systems and autonomy will eventually bring many benefits to private vehicle users – primarily, a shift from human management of vehicle operation to artificial intelligence. This will allow vehicle occupants to carry out tasks other than driving, such as working remotely. However, the added convenience of using a private vehicle may lead to an unfavourable increase in private vehicle usage and congestion (Engineering New Zealand, 2018), hence there may be a need to increase road surface areas. This will increase stormwater quantity, and may reduce runoff water quality, depending on vehicle engine and brake pad technologies. Conversely, complete vehicle autonomy will reduce the urban parking space needed, as vehicles could drop occupants off at their destination and carry on to pick up a new occupant, or be directed to an offsite carpark/street. A reduction in car park space will decrease both water quantity, and the treatable runoff volume.

3.4.3 PERSONAL MICRO-TRANSPORT DEVICES

Battery-assisted micro-transportation devices, such as electric bicycles, scooters, hover boards and skateboards are becoming popular alternative transport modes to private vehicles in urban centres. In late 2018, Neutron Holdings Inc. (Lime) introduced rental e-scooters throughout Auckland and Christchurch CBDs (Wachunas, 2018). Lime have since begun operations in Dunedin and Upper/Lower Hutt. Within four months Lime had hit 1 million rides in New Zealand (Keall, 2019).

The uptake of micro-transportation devices is expected to continue to rise, as battery technology and longevity improves, and manufacturing cost reduces. The motor-assistance of these devices also encourages people who may not normally consider an active transport mode to adopt the technologies (e.g. those who live further out of city centres, or use them to make public transport more convenient, or in places of undulated terrain). This is likely to lead to a reduction in private vehicles during peak traffic times, as well as pressure for local authorities to increase investment in share-used paths. As a result, contaminant load on stormwater treatment systems can be expected to decrease, whilst additional micro-transport infrastructure required may increase impervious surfaces (negatively impacting runoff quantity) or by re-allocation of the transport corridors (with no change in runoff quantity) .

3.4.4 OTHER TECHNOLOGIES

The recent advances and range of devices with the ability to connect to the internet provides great opportunity for improvements in stormwater management. This Internet of Things (IoT) can monitor stormwater systems for changes in temperature, pH, turbidity, flowrate to provide valuable real-time data and enables an adaptive management approach. For example, the adoption of reliable, low-cost, IoT actuators will allow remote control of flowrates into/out of treatment devices (informed by IoT sensors and live weather forecasts) enabling storage volumes to be optimised (Kerkez *et al.*, 2016). This will allow treatment devices to reduce in area, whilst also allowing early detection of pipe blockages for improved water quantity management.

Stormwater treatment technologies are likely to improve in the medium to long-term, which will provide alternative options to meeting regulatory requirements. For example, recent research has shown that typical heavy metals found in road runoff (Cu, Zn, Pb and P) can be captured by filtering through aluminium-based water treatment residual (WTR)-coated mulch (Soleimanifar *et al.*, 2016).

3.5 ENVIRONMENTAL AND CLIMATE CHANGE DRIVERS

The International Panel on Climate Change have provided extensive research to show global temperature increase due to climate change will cause increasing severity of storms including peak rainfall intensities, occurrence of droughts and sea level rise (Stocker *et al.*, 2013). This has numerous implications for existing stormwater infrastructure, and how to account for its future resilience.

Peak rainfall intensities are predicted to increase across New Zealand, particularly for short (1hr) duration events, where increases greater than 10% per degree of temperature increase are very likely (Carey-smith, Henderson and Singh, 2018). The increase in rainfall intensity will have negative effects on existing stormwater infrastructure. Accounting for temperature increase in hydrological models for public stormwater network design has only become a consideration by designers since the release of guidance from the New Zealand Climate Change Office in 2004, based on the commissioned report *Climate Change Effects and Impacts Assessment* (Wratt *et al.*, 2004). Therefore, almost all stormwater infrastructure installed prior to the mid 2000s has not been designed to cope with increased peak rainfall intensities; let alone the effects of additional runoff from future increased impervious areas, as discussed earlier. This leaves ageing infrastructure vulnerable to flooding and erosion. For infrastructure associated with transport, this will create numerous safety hazards and risk of disruption to traffic.

The severity of droughts is also expected to increase throughout the country, except for Southland, West Coast and Taranaki-Manawatu regions (Ministry for the Environment, 2018). This will place stress on water sensitive treatment devices, and may require the integration of irrigation systems to maintain sufficient plant health. Droughts may also contribute to aeolian sediment transport – particularly in the southern regions of New Zealand, where the mean daily wind speed is expected to increase (Ministry for the Environment, 2018). This may cause more sediment deposits on road surfaces, increasing sediment deposition in the receiving environments.

Local Government New Zealand (LGNZ) recently released a report into the effects of climate change-induced sea level rise on national infrastructure (Simonson and Hall, 2019). The report estimated the replacement value of national three waters infrastructure is $1.4 billion, for a scenario of 0.5 metres sea level rise, and $2.6 billion for a scenario of 1 metre sea level rise. The effects of sea level rise on stormwater range from erosion and scour of coastal outlet structures to the reduction in hydraulic capacity of gravity-driven pipe networks (flooding/back flow at network entry points such as street catchpits).

Lastly, global increases in mean temperatures will also affect the physical habitats of both natural receiving environments and treatment wetlands/ponds. Higher runoff temperatures from impervious road surfaces will put undue stress on flora and fauna in receiving environments; for wetlands, this may cause a reduction in treatment efficiency and an increase in maintenance/replacement costs of vegetation.

4 DISCUSSION AND CONCLUSIONS

In the short term, transport environment effects on stormwater quality and quantity management will be driven by regulatory changes/requirements. This will improve water quality/quantity management, but may be harder to achieve without other drivers coming into play.

In the medium term, effects from technologies, densification/population growth will become significant. Profound changes are expected to transportation due to social and technological drivers. However, these changes and their timing are difficult to predict. Stormwater design will need to be more space-efficient/multi-purpose/integrated with urban design elements. This will relate well to other drivers – streets in CBD’s more pedestrian and micro-transport orientated. Water-sensitive designs will need to consider resilience for future climate.

In the long term, effects from climate change will be felt. Regulations and design requirements need to be considering these effects now to ensure design lives are met. Design requirements will need to be adaptive - to continuously stay on top of latest hydrological model predictions.

Profound changes are expected to transportation due to social and technological drivers. However, these changes and their timing are difficult to predict.

While we can identify many drivers for change it is challenging to understand their impacts and timing. However, it is clear that water is becoming increasingly important and impacted in our country. The future is unknown and complex and there is more pressure on us to get it right, Therefore, more coordination of water outcomes are required through central government, local government and industry to produce stormwater guidance and evolve best practice. This could include national design standards and national certification of treatment devices. With an uncertain future the use of scenarios studies is useful to test policy as was done by the TOFS study. Similarly, stormwater design should consider different scenarios for climate change, land and transport futures and pollutant loads.

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