



Jean Monnet Module
SCHOOL OF ADVANCED SOCIAL STUDIES

Sustain4EU: Enhancing European Civic Practices and Sustainability as the articles for this thematic issue were collected within this project.



With the support of the
Erasmus+ Programme
of the European Union

The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Research in Social Change

INCREASING SUSTAINABILITY IN AUCKLAND ROAD CONSTRUCTION BY USING PLASTIC WASTE

Manoj R. Asrani, Indrapriya Kularatne*

Department of Applied Management, Otago Polytechnic Auckland International Campus, Auckland 1010, New Zealand

Abstract

The purpose of this paper is to explore the use of plastic waste to increase the sustainability of road construction in Auckland. An exploratory research strategy was used based on interviews conducted with infrastructure company and waste management company managers, road construction practitioners, academic experts relevant to the roading industry and technical personnel. Thematic analysis was used to analyse the data for insights. There are some concerns regarding the quality and performance of roads affecting socio-sustainability, for which research is advised from the Auckland perspective. Research is recommended in the subject of recycling other waste material such as glass and rubber into roading all over New Zealand (NZ). Moreover, research is recommended specifically for walking and cycling tracks, which is a focus of the Auckland Council currently. The infrastructure companies and the Auckland Council must work together for incorporating plastic waste in roading. Companies can achieve higher sustainability as they will make a profit by saving costs, benefit the society by providing better quality and performance of roads and help the environment by green manufacturing. By using plastic waste, the Auckland Council can meet the targets of decarbonising the transport in Auckland by the year 2040; this is also a step towards the NZ targets of the 2030 Sustainable Development Goals.

Keywords

plastic waste • road construction • sustainability • recycling

1. Introduction

Auckland is witnessing the maximum yearly growth rate in New Zealand (NZ), and it is already grappling with managing the growth in a population facing traffic blockages and complicated roadway systems. Consequently, the NZ Government and Auckland Council have designed a development strategy (Regional Land Transport Plan [RLTP]) to organise about \$37 billion to upgrade the infrastructure in the next 10 years (Auckland Council 2021a, 2021b). The roading infrastructure has been allocated a major part of the funds. Emphasis is placed on the construction of high-quality, cost-effective and sustainable road infrastructure to be completed within the assigned time limit. Priority is being given to companies practising sustainable procedures and adopting innovative thinking, thus, encouraging and enforcing infrastructure companies to follow all aspects of sustainability. However, the cost of roading is continually rising due to increases in raw material prices, high transportation costs, time delays affected by inflation (Lessing, Thurnell, and Durdyev 2017). Time delays, in turn, occur due to shortages of material or transport lags caused by poor road networks

(Stuff 2021, December). Additionally, difficulty in using materials in prefabrication or specific construction processes and particular quality requirements during actual construction may also result in project delays. Any form of delay affects construction schedules and causes economic concerns and results in disruption of peace and routine functioning of society (Parrangan, Rachman, and Tanijaya 2021). On the other hand, the quality of roading has been doubted. The number of road accidents between the years 2014 and 2017 has jumped by 78%. Despite lockdown, 320 tragedies have occurred in the pandemic times, troubling the community (Greater Auckland 2018). Lastly, the infra-company activities create noise, as well as air, land and water pollution, damaging the surrounding environment, requiring the attention of the Auckland Council (Leung et al. 2017). Hence, there is a need to enhance the sustainability practices of infrastructure companies.

Furthermore, plastic pollution is a global threat and harms humans, animals and sea life equally, including Auckland. Plastic consumption in Auckland is ever increasing. An alarming 58% of plastic consumption goes to landfills, with expectations

*Corresponding author e-mail: indrapriya@op.ac.nz

of dangerously doubling to 3.2 million tonnes in the next 10 years (Fischer 2020), a reason of concern for the Auckland Council. Otherwise-usable land is occupied by plastic waste (PW), degrading the land and polluting the surroundings, being detrimental to the Auckland community and the environment (Roselyn and Kurniawan 2019). Thus, there is an urgent need to recycle PW and make it useful in different industries in Auckland.

New composite materials have been developed elsewhere using PW, capable of being used in the roading industry, for example, Plas-Mix in NZ and Asco Asphalt in the United Kingdom (UK) (Sasidharan, Torbaghan, and Burrow 2019). Many countries recycle PW in different forms to use it in road construction beneficially, such as bitumen additive in India, aggregate coating in India and the UK, commercial pellets for asphalt mix (the UK) and paver tiles in Ghana and India. Interestingly, Holland uses PW to make an entire prefabricated modular structure that forms a part of the actual road (Sasidharan, Torbaghan, and Burrow 2019). Surprisingly, here in New Plymouth (a city in NZ), PW was used in small quantities as an aggregate binder in constructing roads (Hall and White 2021). However, Auckland roading still follows the traditional methods of construction involving asphalt, aggregate and sand mixes without using PW in any form (NZ Transport Agency [NZTA] 2018). In addition, there are no published research articles or journals that support the use of PW in any form for the construction of Auckland roads.

Thus, given the acute need for speedy infrastructure development in Auckland and an assigned budget in place, the use of PW in Auckland roading must be explored. In doing so, the NZ Government agencies and infrastructure companies can jointly tackle the plastic “pandemic” in Auckland as follows:

- there will be better management of PW, thus reducing plastic pollution and benefitting the society;
- PW can substitute non-renewable materials utilised in roading, proving to be environmentally friendly;
- the ready availability of PW all over Auckland eliminates material shortage and their transportation issues, saving project time and money.

This research will be used for establishing company issues, new possibilities and different growth opportunities by embracing PW in the Auckland Road industry to gain benefit. Roading companies then can willingly incorporate the eco-centric, three-nested-dependencies sustainability model. As per this model, companies must follow practices that first address the environmental concerns, prioritising the health of our planet over making profits (Yacob, Wong, and Khor 2019), thus satisfying the Auckland Government’s environmental apprehensions and simultaneously boosting companies’ profits, leading to a winning scenario. This accomplishes the research objective of exploring the use of PW to increase

sustainability in Auckland roading, enabling an innovative solution for the plastic pollution in Auckland.

1.1. Research aim and questions

The aim of this research is to give information and understanding about using PW in the construction of Auckland roads. Accordingly, infrastructure companies can achieve high levels of sustainability concurrently by reducing plastic pollution and readily adopt the nested model of sustainability to attain a higher status in a highly competitive business atmosphere.

Managers of infrastructure companies are continually looking for different optional ways to decrease expenses, reduce construction time and upgrade their construction quality. On the other hand, levels of PW in Auckland are increasing sharply (Fischer 2020). The Auckland Council has framed policies aiming for zero waste by 2040 and is encouraging innovative ideas for the purposeful recycling of PW (Auckland Transport Alignment Project [ATAP] 2021). Many countries are currently utilising PW in various ways in roading, as mentioned above. Hence, exploring the use of PW in Auckland roading in this research brings us to the following questions:

1. How can the use of PW in Auckland road construction improve economic sustainability?
2. How can the use of PW better the quality of Auckland roads and enhance social sustainability in Auckland?
3. How can the use of PW in the Auckland construction industry help environmental sustainability?

This exploration can help roading companies and Auckland government agencies gain insights into using PW for construction activities to resolve the plastic epidemic and gain monetary benefits together.

1.2. Literature review

This section discusses Auckland roading from all the three aspects of sustainability, namely the environment, society and economic factors, based on available literature. Additionally, pollution due to plastic in Auckland, role of Auckland Council in the road industry and how other countries are successfully using PW in road construction are discussed in detail.

1.3. Economic sustainability challenges

The Mill Road upgrade project in South Auckland has been cancelled due to rising construction costs (TVNZ 2021a, 2021b). This report shows that the infrastructure companies are facing economic challenges. Reasons such as trade and tariffs problems, environmental policy and rules, labour and raw material costs are the main contributors to the rising costs in roading. Expenses increase due to compliances such as soil erosion and sediment controls and green road certifications achieved on the basis of road design and construction methods (Auckland Design Manual 2016). Roading activities

in Auckland need milling, filling and finishing in a single day, requiring higher productivity and skilled workforce, which cost more (Karimian et al. 2019). NZ continually faces labour shortages, highlighting the need to increase productivity to save costs. Moreover, the wages in NZ are increasing (Employment NZ 2021). Consequently, the shortage in skilled labour and inflationary pressures are increasing labour costs continually. In addition, average liquid asphalt prices per tonne have risen sharply about 15% when compared annually due to shortages in bitumen. NZ has low quantities of natural bitumen, and 50,000 tonnes/year of processed bitumen is still imported from Asia-Pacific refineries (NZTA 2019) to meet the demand. The imports further add to the final costs. Similarly, aggregate prices rose 10% through 2017 and need to be transported from places farther away due to encroachment of urban land (Radio New Zealand [RNZ] 2019). Stuff (2019a, 2019b) supports this view by comparing quarry prices to chips averaging to \$22/tonne, but transportation escalates it to about \$34/tonne. Issues of traffic congestion, poor road network and restrictions in Auckland cause a further setback to transportation, causing delays (Greater Auckland 2020). Such delays not only burden the project cost factor but also cause inconvenience and pollution, in addition to disturbing community peace due to construction blockades (Auckland Transport 2021a, 2021b).

However, Velenturf and Jopson (2019) explain that many companies find the cost of implementing, maintaining and managing sustainability practices high. Moreover, several times, the companies do not find any financial benefit to involve in such practices. As a result, roading companies try to avoid them, accept them in part or apply them due to mandatory necessities. According to Kivilä, Martinsuo, and Vuorinen (2017), infrastructure companies have the tendency to relax and even suspend sustainability practices once obligatory requirements (such as permits or licences) are received. Thus, government regulations, shortages of materials, transportation issues and schedule delays drive up costs and harm the economic sustainability of roading companies.

1.4. Social sustainability challenges

Auckland roading has always been scrutinised for issues relating to pothole formation, dust mitigation and safety improvements as the local governing boards receive complaints against them. Auckland experiences climate changes, causing extreme fluctuating temperatures and unprecedented rainfall, which create melting, cracking, potholes and erosion of roads (Karimian et al. 2019). According to the *NZ Herald* (2019), a heat wave caused bitumen to melt due to which the vehicles were covered in a sticky mess and also in danger of accidents due to the slippery road surface, leading to hazardous driving conditions; similar incidents have been reported in 2017 and 2018. Moreover, Auckland Transport (AT) received around

275 compensation claims from car owners due to potholes created by rainfall, which damaged their vehicles (Stuff 2018). Likewise, the increasing pressure of vehicular traffic is causing faster erosion of roads, calling attention to maintenance and safety measures (Greater Auckland 2020). Such incidents exhibit the poor quality of roads as being dangerous for people, which impacts the social sustainability of roading companies.

Additionally, Chen et al. (2017) explain that roading activities cause pollution, which is unhealthy not only for people in surrounding areas but also for their on-site employees. Air pollution in Auckland caused by infrastructural activities such as roading create health hazards such as cough or shortness of breath, affecting health in the short term and having long-term implications, necessitating green infrastructure practices (Boyle 2014). According to the Auckland Council Technical Report (2019), roading activities are causing water pollution, leading to contamination of water sources and spreading of unsafe drinking water (Belayutham, Gonzalez, and Yiu 2016). Most obvious and immediate is the noise pollution that causes mental stress, sleep disturbances and hearing disorders.

Further, roadblocks due to road construction are safety hazards and also upset routine commuting and daily activities of people, frustrating the community (Klaeger 2013). Many bus routes had to be changed in the Central Business District (CBD) due to roadblocks produced by roadworks. Moreover, during road construction, the work staff at the sites block road areas more than required for constructing at a faster pace (Greater Auckland 2021, May), which reflects low productivity in construction activities (Karimian et al. 2019), unfavourable for society at large. Hence, roading companies need to improve their social sustainability practices.

1.5. Environmental sustainability challenges

The NZ Government and Auckland Council are maintaining continuous pressure on roading companies to increase their environmental sustainability practices and have designed several policies around it. For example, the Auckland Council has framed specific guidelines to be followed in developing the network-and-utilities infrastructure for preserving any natural heritage and the coastal environment. The Greater Auckland (2020) corroborated this view, calling to conserve aggregates used for roading as their depletion causes landslides and topsoil erosion, resulting in severe environmental damage. According to Newman et al. (2012), the consumption of non-renewable materials (including bitumen, used for asphalt production) is a cause for environmental concern, and alternatives must be found. This argument gains support from the NZTA (2021), as they emphasised on the necessity of recycling materials and on recycling techniques for sustainable roading throughout NZ.

Additionally, road construction in Auckland creates air and water contamination (Boyle 2014), which affects plants, animals, bacteria and fungi, resulting in an imbalanced ecosystem, loss of biodiversity and disruption in the food chain (Reed et al. 2021). Moreover, there are carbon emissions during the manufacturing of bitumen in Marsden Point Oil Refinery, Auckland (Adkin 2018) and due to the use of construction equipment and procedures reported in the survey by the Auckland Council (Xie et al. 2019.), which cause climate changes and must be controlled (Chen et al. 2017). Therefore, roading companies must ensure that activities conform to environmental sustainability.

However, according to Steyn, Holleran, and Nam (2018), along with Imran and Mathews (2011), infrastructure companies do follow several kinds of sustainability practices. Roading companies use solar panels as the energy source, environment-friendly biodiesel for vehicles and hydrogen fuel cell technology, in addition to having zero emissions during heavy machinery operations at construction sites. Griffiths, Boyle, and Henning (2018) are supportive, agreeing that many infrastructure companies provide workers with appropriate personal protective equipment (PPE). Additionally, infrastructure companies make use of acoustic barriers, controlling noise pollution, and have a good monitoring system for chemical and waste disposal to avoid land and water pollution, catering to social welfare (Blom and Guthrie 2018) and adhering to socio-sustainability practices. Lastly, roading companies are trying to manage costs by using automated technology for effective inventory and supply chain management (Brown and Visser 2018).

But sustainability has long-term targets based on futuristic goals and always requires acceptance of new and innovative ideologies (Business Govt. NZ 2021). Thus, the sustainability challenges of the Auckland roading industry make a relevant case for exploring the use of PW in Auckland road construction.

1.6. Plastic pollution in Auckland

According to the *NZ Herald* (2019), the plastic pollution in Auckland is spiralling, with about 3 million tonnes estimated to reach landfills, doubling in the next 10 years. De Bhowmick, Sarmah, and Dubey (2021) explain that 32% of the plastic packaging ends up in the oceans, which is a threat to marine species and releases microplastics, which are unhealthy for people as they affect the food chain. PW chokes and suffocates wildlife as the animals may confuse it for food. Stuff (2020a, 2020b, 2020c, September) confirms similar issues in Dome Valley, where people protested against landfill activities that cause toxic fumes, presence of leachates in water and greenhouse gas emissions that cause atmospheric contamination. Thus, PW is causing severe air, water and land pollution. Additionally, according to Auckland

Council (2021b), NZ consumes 1 billion single-use bottles annually (which are thrown away) but is incapable of handling the PW that it produces, which ends up going to landfills. TVNZ (2021a, 2021b) reported that NZ has exported more than 97,000 tonnes of PW to Malaysia and Thailand. The helplessness of NZ in recycling its PW has been exposed and the global green image of NZ is under threat due to plastic pollution.

Nevertheless, the Auckland Council is taking several steps to manage PW. Currently, an upgrade in the Visy recycling facility in Auckland and the new plastic-sorting technology used has enabled the recycling of nearly 34% of the entire Auckland PW domestically rather than sending it overseas (Gerrard 2020). Moreover, PW from products such as pens is being used to make garden beds, park benches and playgrounds by collaborating with furniture-manufacturing enterprises, making it environment-friendly. But the use of PW in roading is unheard of. Additionally, there is no available literature on PW incorporation in the Auckland roading industry. Thus, this research can prove to be advantageous for the roading industry and the Auckland Council.

1.7. Role of the Auckland Council in the roading industry

The Auckland Council is primarily responsible for all roading activities in Auckland. Out of the \$37 billion planned for Auckland Transport under the Regional Land Transport Plan ([RLTP] 2020–2030, Auckland Council 2021a, 2021b), the Auckland Council will contribute about \$10 billion. Auckland Transport (2021a, 2021b) explains that such investments are arranged from the Regional Fuel Tax (RFT), the National Land Transport Fund and, most importantly, the “toll” collected from motorists. RFT is applicable “only” in Auckland, 10 cents plus Goods and Services Tax (GST), a net of 11.5 cents/L on fuel acting as a double tax (Auckland Transport 2021a, 2021b). As a result, the fuel consumer pays heavily and unfairly in Auckland. The Automobile Association (AA) is continuously campaigning for RFT removal, which will save Auckland people’s money (AA Motoring 2021). Thus, the Auckland Council is not taking active steps to reduce roading costing and burdening Auckland locals.

AT is a controlled organisation under the Auckland Council and makes the roading policies. AT lays down the specifications of roading material such as asphalt, their recycling and reuse back in roading provisions (AT Code of Practice 2013). However, there is no policy for inclusion of any new materials in recycling or otherwise. The NZTA (2021) has a particular provision for sourcing local materials for reducing the transport distance of materials. AT also lays down best practice guidelines on how the materials are to be transported, at what temperatures and how to ensure proper handling to safeguard the working personnel. Additionally, construction processes, such as ambient air temperature above 5° and wind speed

lower than 25 km/hour for chemical spray, are defined by the AT (NZTA 2021). Such provisions can easily support the use of PW in roading. AT requires contamination to be reported, holding the designer “solely responsible” for the material and to justify the chosen construction design. Thus, AT has an indirect and stringent control over production companies. Such policies deter the companies from experimental use of alternative materials such as PW or construction processes, discouraging new technology.

AT implements tools such as Quality of Service (QoS) for cycling pathways, which measure the aesthetic performance features (user safety, mixed traffic concerns) effective for the optimisation of return on investment (ROI) during construction of those paths (AT 2016). But there is no measure of the actual performance of roading materials or the process of construction, for instance, tools to measure bitumen performance on roads, so that it can be improved to stop melting. AT is experimenting on increasing road performances in terms of traffic management by innovative light show for decongestion and lane control. Advanced technology is being adopted using geotextile optic fibre for monitoring water and land movements, real-time cameras and mobile setups for global positioning systems (GPSs) for information to upgrade the health of Auckland roads (ATAP 2021–2031, 2021). However, no advancement has been made in the use of new materials in roading, and no new or alternative technology is being attempted by the Auckland Council.

Therefore, the Auckland Council should find ways to decrease the monetary pressure it creates on people and consider different approaches towards roading companies, which encourage them to adopt innovative ideas.

1.8. Other countries using PW in road construction

Repurposing PW into asphalt can enable clean and green roading (Wu and Montalvo 2020). PW was incorporated in India about 20 years ago after realising about the similarity of chemical properties between plastic and bitumen and the fact that both are petroleum by-products (Manju, Sathya, and Sheema 2017). PW can comfortably mix in and replace almost 12% of the bitumen to bind the aggregates, saving natural resources (Awoyera and Adesina 2020). Thus, plastic roads are not solid plastic strips or bands but common general roads.

India uses raw PW directly in shredded form, Ghana makes blocks and bricks, the UK makes commercial plastic pellets to be mixed in roading materials, while Netherlands makes prefabricated plastic blocks (Sasidharan, Torbaghan, and Burrow 2019). Manju, Sathya, and Sheema (2017) explain that PW in roading improves the wear-and-tear life, resulting in higher performance and lifespan of roads. Moreover, the toughness of roads increases, reducing the creation of potholes and thus lowering maintenance-related issues and costs with

higher quality. White (2020) corroborates that plastic roads have better surfaces, enabling better absorption of sound, fumes, smog and gases, resulting in lower vehicular noise and air pollution, which, according to Sorvig and Thompson (2018), benefit society and environment. Consequentially, roading companies achieve higher sustainability in the use of PW.

Nevertheless, Popescu and Burlacu (2017) argue that toxic sulphur fumes and greenhouse gases are emitted during the construction process, causing environment pollution, and PW also releases chlorine gas, which is unhealthy for on-site workers. Similarly, according to Awasthi, Shivashankar, and Majumder (2017), pollution continues after construction also, due to microplastics released in the air and flowing into water. But Sasidharan, Torbaghan, and Burrow (2019) contradicts such views, explaining that road material is relatively inert, a solid block of asphalt, and thus cannot create microplastics. Additionally, microplastics and pollution can be managed by controlled manufacturing techniques and using advanced scientific processes such as biofilters (Laskar and Kumar 2019). On the other hand, roading technology using PW is growing and spreading in Asia, Europe and, specifically, the UK. *According to the magazine Yale Environment 360 (2021)*, many countries such as Vietnam, Mexico, Philippines and even the United States have constructed roads using PW using different processes and technology. Ghana, for instance, uses PW with sand to make blocks having PW as high as 80%, making persistent efforts to follow the 3R circular model (reduce, reuse and recycle), targeting to eliminate 1.1 million tonnes PW by 2030 (Tulashie et al. 2020). According to MacRebur, a British company manufacturing commercial plastic pellets used in roading and supplying them to other countries, every tonne of bitumen replaced by PW reduces equivalent tonnage of CO₂ emission during bitumen manufacturing, thus benefitting the environment (MacRebur Annual Report 2021). Consequently, MacRebur is making attempts to formalise PW inclusion in UK roading. The Netherlands pursues a novel technique without traditional asphalt (Plămădeală, and Plămădeală 2019). For starters, they have made a cycling path using prefabricated PW hollow modules, which have very low production cost and can be easily installed, saving time and benefiting society. Thus, plastic roading technology is gaining new grounds to support and boost sustainability for infrastructure companies. However, many countries are only recently using PW in roading for less than 8 years, it may be too early to show premature failure as road life is about 30 years (Sasidharan, Torbaghan, and Burrow et al., 2019). This view is supported by Conlon (2021), explaining that data available on the performance of PW roads and their endurance over time is lacking and insufficient, creating potential issues using PW. In order to balance such risk probabilities, Australia has started building smaller local roads using PW (White 2020).

Thus, several countries are using different technologies incorporating various levels of PW carefully with good results, experiencing higher sustainability levels.

1.9. Gaps

According to the NZTA (2018), NZ roads are constructed using asphalt concrete, which is a mix of local crushed stones (aggregates) and bitumen. Roads using only concrete (sand and gravel bonded by cement) were built before 1945 and are not currently being used in NZ (NZTA Road Pavements 2021). However, to date, very little is known about PW as a material in roading. Even according to the NZTA Road Pavements (2021), there is no inclusion of any new materials in Auckland roading. Studies by Neaylon et al. (2019) verify that there is optional and limited application of plastic (not from PW), that too in the thin top surfacing layer of roads. What is not clear in the literature review is the use of PW in core road building in Auckland.

Auckland constructs roads conventionally using asphalt and aggregates with long-established conservational technology (Karimian et al. 2019; NZTA 2021). There is uncertainty about the use of any new technology using PW in Auckland roading. Additionally, despite plastic mixing into bitumen roading to the extent of 15% without compromising on road quality (Williams 2018; Manju, Sathya, and Sheema 2017), there is no clear evidence for the use of PW in any form in bitumen or asphalt manufacturing processes, as seen in the literature review.

New Plymouth city in NZ has built plastic roads using simple PW solely due to the efforts by the local Council. They used 83,000 yoghurt and milk pots amounting to around 0.5 tonnes as a drive to achieve the zero-waste policy that they have set as the target (Hall and White 2021). However, little attention has been given by the Auckland Council to promote such use of PW in Auckland roading despite having ambitious targets of 13% carbon reduction by 2040 (ATAP 2021).

Finally, to date, no literature incorporating PW in Auckland roading is accessible. These discussions above reveal a gap in the use of PW in Auckland roading, which can be examined by this research.

1.10. Scope for PW use in Auckland roading – rationale for the study

Auckland and all of NZ receive their bitumen from Marsden Point Oil Refinery – the only one in NZ – catering to 70% of the domestic consumption, with the remaining 30% being imported (Stuff 2020a, 2020b, 2020c, November). As a result, NZ will have to rely on imports completely, leading to a fuel security risk for the roading industry. Problems such as shortages of material, issues of quality, storage, and management of bitumen cause concern. According to Karimian et al. (2019), Auckland has planned for record infrastructural investment without any backup plan for

materials. Much of the challenges would reduce if PW is used in Auckland roading (Kehinde et al. 2020).

Additionally, Auckland is concentrating on expanding the road network to remote areas and constructing more arterial routes (ATAP 2021). Construction of new cycling and walking paths is highlighted to enable the shift in mode away from private vehicles, whereby PW can be trialled as in Australia (White 2020). According to the ATAP (2021), the project specifically provides \$742 million for new technology programmes and towards innovative recycling materials (Auckland Council 2021a, 2021b, June), which can be used for adopting PW, in addition to providing \$1,114 million for measures that deliver network optimisation, safety and efficiency benefits (AT 2021), thus making a case for studying PW in Auckland roading. Moreover, around 3,000 oil containers made of plastic were used in constructing Christchurch Airport roads, which reflects the concern of the authorities and their enthusiasm for promoting “Go circular” sustainability (Hall and White 2021), which can inspire the Auckland Council. Such concern is important because, according to Omisakin and Roy (2018), only 40% of the plastic containers in NZ are recycled.

Further, the Auckland Council is giving priority to decarbonisation of the transport infrastructure (ATAP 2021). Auckland has set up its own Low Carbon Action Plan to reduce 40% greenhouse gases by 2040 (Harker, Taylor, and Knight-Lenihan 2017). Lastly, according to Stuff (2019a, 2019b, July), NZ signed the agenda of the United Nations Sustainable Development Goals (UNSDGs) in 2015, targeted to achieve the goals by 2030, but they are far lagging behind. Using PW in roading will be useful in monitoring and measuring the progress towards these goals, supporting this study.

2. Materials and Methods

Primary research was done to evaluate the gap in the literature, while exploratory research strategy was used to get a greater understanding of the problem. Qualitative data was collected by conducting semi-structured interviews. Primary research is usually carried out when there is need to gather recent data that is useful for a specific research context (Kumar 2018). Moreover, according to Rahi (2017), the purpose of exploratory research is to seek new insights and find out what is happening for which a qualitative approach is useful. This research focussed on obtaining new insights into current roading sustainability and PW issues specifically in the Auckland context. Similarly, in a study investigating the suitability and monetary benefits of replacing sand partially by copper tailings in road concrete, used in Zambia, an exploratory research design was used (Muleya et al. 2020). Additionally, using PW in roading has been studied in other countries such as India, UK, Ghana and even NZ

(New Plymouth), as seen above. But it has not been intensively researched upon in Auckland despite the existing issues discussed above. Even while examining applicable literature, only a single article was found (Khati and Boyle 1999) evaluating the use of different recyclable materials (including PW) for sustainable NZ construction. Therefore, it became necessary to obtain the opinions and motivations of experts in this topic specific to Auckland. According to Hammarberg, Kirkman, and de Lacey (2016), for a qualitative research methodology that is exploratory in nature, interviews are best suited and enable good outcome. Moreover, this research topic and the related questions have the potential to provide insights, which can develop ideas and hypothesis for quantitative research. Considering all the factors above, primary research using qualitative exploratory research design is most suited for this particular research topic and has been chosen.

This study has been chosen and limited specifically to Auckland because it is the biggest international city, growing @1.6% yearly and requiring infrastructure development. The NZ Govt has set up a 31-billion-dollar investment programme, for which this research could be helpful.

2.1. Data collection

Qualitative data was gathered from semi-structured interviews conducted with 12 people with relevant expertise. The number of interviewees was limited to 12 as interviews consume large amounts of time. A convenience sampling technique was used for selecting the participants since many were known to the researchers and it was an easy and inexpensive method (Etikan, Musa, and Alkassim 2016). Additionally, the participants also provided references, who participated voluntarily to complete the interview process aligning with the snowball technique (Ghaljaie, Naderifar, and Goli 2017).

Semi-structured interviews were conducted, which is a method favoured by many researchers to gather new data relevant to the research subject. The interviewees' answers are used to connect available data sources and verify information, leading to good conclusions (Roulston and Choi 2018). An open-ended questionnaire was framed to get answers related to economic issues, environmental concerns, societal troubles and quality of roads, pertaining to the use of PW, for insights into each of the research question.

Conducting semi-structured interviews was appropriate for this research. Evans and Lewis (2018) explain that, firstly, data obtained is easily analysed since the researcher prepared the questionnaire beforehand to keep the interviewees on the topic. Secondly, open-ended questions used in semi-structured interviews give the opportunity to ask additional questions depending on the answers of the interviewee. Consequently, the researcher learns the reasons behind the answers and gets deeper understanding of sustainability challenges and plastic pollution issues. Thirdly, the interviewees can express

their knowledge, experiences and opinions freely, enabling rich, insightful and even sensitive information regarding the use of PW in Auckland roading. Finally, semi-structured interviews offer a two-way communication platform, allowing detailed information to surface when exploring the use of PW in roading.

Data was collected face to face and using online platforms such as Microsoft Teams to adjust meeting time and place according to convenience. However, the interviewer had to wait patiently for the agreement of the interviewees and travel long distances to meet interviewees. Busy schedules caused some hindrances in conducting interviews but could be completed after online-Teams meetings. Thus, the researcher faced some challenges that were cleared eventually due to determination. Data saturation was observed after completing 11 interviews. The interviews produced adequate data to verify the analysis of the literature review.

The researchers received ethics approval for this project from the Research Ethics Committee of Otago Polytechnic Auckland International Campus. Individual details of all the interviewees are confidential. Code names such as T1 (technical experts such as site engineers, quantity surveyors), A1 (academic experts such as professors and researchers in the relevant field), P1 (actual practitioners in roading), WM1 and M1 (managers in roading waste management companies) and RE1 (real estate practitioners) are used for maintaining anonymity, making them free from any kind of harm. The researcher had taken varied perspectives to encompass all-round information related to the topic. Inputs of RE1 were important from the common man's perspective but relevant to the topic.

2.2 Data analysis

The researcher has used thematic analysis for studying the interview data, which is the most popular method in qualitative research in which interviews are conducted. Moreover, it is an iterative process for organising random data (Kiger and Varpio 2020). In addition, an inductive analysis technique was used. According to Armat et al. (2018), inductive analysis is a process of coding the data without trying to fit it into a pre-existing coding frame or the researcher's analytic preconceptions. Further, all the interviews were analysed several times for extracting common and repetitive themes based on following the inductive approach, which is not only descriptive but also exploratory (Kiger and Varpio 2020). Therefore, effective results can be obtained in this research.

A systematic literature review has been done related to the topic areas such as sustainability challenges for roading in Auckland, Auckland Council's roles and influence, and plastic pollution in Auckland. Such secondary data collected will be compared and analysed with both the findings of this research and previously published literature to shape the result of this research.

2.3. Data analysis process

Data analysis process followed a linear process of data familiarisation, coding, defining and naming themes from the codes to produce a report (Williams and Moser 2019). Transcribed data was read multiple times for familiarisation. A progressive data-coding process was implemented using open, axial and selective coding. Codes were collated with supported data to form themes and sub-themes and thereafter revised to get the final themes following thematic data analysis (Neuendorf 2018).

Finally, the four following predominant factors were found, which are discussed in the report below:

1. Economic benefits of using PW
2. Auckland perspective of PW
3. Environmental benefits of PW
4. Role of Auckland Council

3. Results and Discussion

This section presents the findings from the interviews considering the themes created using thematic analysis and the discussions thereof regarding the use of PW in Auckland roading and how it affects roading sustainability issues. Discussions are made by analysing and comparing the existing literature available with the findings to address the research questions.

3.1. Factors affecting the cost of roading: managerial perspective

Infra-company managers and owners are continuously finding ways to reduce the ever-increasing cost of road construction. The literature review well establishes these concerns and is well supported by all respondents. Labour, material and time-delay costs affected by inflation were the top answers in the list. A2 comments, *"we're already heightening the cost of everything we do; lack of raw materials within New Zealand; companies are looking for cheaper options; apart that, there are many issues like labour shortages, consents from Government and waiting time inflation adds up the costs [sic]"*. PW forms a cheaper substitute reducing costs; this supports the view of A2 of *"companies are looking for cheaper options"*. Thus, 90% of the respondents said that PW can be mixed in asphalt partly, with T1 stating, *"so single use plastic. We can use it with asphalt"*. Roading companies stand to benefit as PW is basically available with no cost and this is supported by P2 commenting, *"Costs less money of course; there are heaps of plastic"*, giving a direct benefit. Bitumen is highly priced, which is only set to increase with the closing of the Marsden Point Oil Refinery. P2 also stated *"they tried their best to monitor the price from overseas"*, which shows that infrastructure companies face cost issues. Additionally, NZ's

complete reliance on imports raises concerns regarding meeting demands, quality, storage and time schedules, which again escalates costs. However, WM1 clearly mentioned, *"Oil refinery closes down, that will be the catalyst for waste plastic"*, which opens up a window of opportunity for Auckland roading. A3 quotes *"substituting 10 to 12%, it's significant"*, and all the experts agree that PW can be available all over Auckland easily.

Further, transportation costs were another factor worrying the infra-companies as materials are often procured from far-off places, confirmed by T1, *"long distance people can deliver only four loads a day, so the money is increasing"*. While all the respondents agreed that transportation cost of materials is high, they stressed that delays occur in and around Auckland because of congestion or road network issues. Import-related issues are other reasons for delay. Such delays disrupt the supply chain, cause wastage in labour time, as confirmed by P1: *"Bad traffic, yes, and so we changed our work time from very early"*, and increase project duration ultimately, adding to inflation costs. T1 agrees, stating that, *"Material supplies delay due to that all inconveniencing and calculation on the project going up [sic]"*. The ready local availability of PW offers convenient transportation to sites or production factories and reduces time delays and can thus mitigate the costing concerns. Notably, PW can directly infuse with the excavated asphalt at the site itself (White 2019). Thus, there is no extra material cost, no wastage in time and involves less workers, saving labour costs. However, WM1 cautions that transportation of large quantities of PW incurs expenses and creates potential hazards, which is confirmed by T1, who states, *"six-tonne plastic waste, it cost me 1000 bucks"*. But these costs are negligible compared to the net benefit in managing short supplies, as well as the overall cost and time saved, and can be ignored.

Lastly, according to Karimian et al. (2019), roading companies face shortages in skilled labour and need to increase production efficiency to reduce the cost pressure. RE1 confirms, stating, *"I see it takes a lot of time and I think they can be more efficient to work as I see them standing all the time"*. According to Sasidharan, Torbaghan, and Burrow (2019), Ghana speed-produces cheap PW blocks using 80%PW and 20% sand in factories with simple road-laying techniques requiring less manpower and low-skilled workers, thus resulting in lower roading cost and simultaneously increasing efficiency using PW. According to the British Broadcasting Corporation (BBC) (2021), India witnessed savings of roughly £480/km of road after using PW.

From the discussions above, the use of PW in Auckland roading can reduce raw material cost, avoid supply issues in terms of transportation delays, achieve a faster processing time with lower temperature requirements, have no separation problems and require low-skilled labour, resulting in lower

manufacturing costs correlating with the theme of economic benefits. Therefore, using PW will significantly boost the economic sustainability of Auckland roading companies.

3.2. Understanding the quality of roads

The Auckland Council is continually aiming to improve the quality of roads and has allocated special funds for innovative ideas and technology improvements thereof. All respondents agree that Auckland does not use PW in roading. Their answers are based on their area of expertise and how other countries use PW in their roading processes. Accordingly, 75% of the 12 respondents replied that plastic, by its nature, is difficult to destroy and can provide extended road life. T3 quotes, *"because plastic is always so durable it doesn't just go"*. According to Manju, Sathya, and Sheema (2017), PW not only extends road life but also boosts the immediate physical properties such as toughness and flexibility, friction, temperature variance (-23°C to 80°C) and water resistance. Similarly, A1 agrees, *"rainy seasons we have tested for the water quality, water absorbance, everything. So when we compare with the normal roads, plastic-based roads have a good life"*. Additionally, all 12 experts agree that asphalt will not be completely replaced unless a completely new technology is used. PW forms a part of materials and enhances the quality of roads while maintaining the other crucial road properties.

Currently, residents in Auckland have been complaining about potholes and road accidents due to cracking because the roads are unable to handle vehicular pressure since the number of cars have increased significantly since 2010 (Auckland Council. 2021b). Neaylon et al. (2019) confirm that using PW in roading enables high-quality and well-maintained roads that can bear heavy vehicular pressure, withstand temperature differences, and also have better stopping distances helpful to avoid accidents. T3 reiterates: *"So these roads would last. it's better quality, it will not need maintenance"*, supported by A1, *"potholes will be less"*, providing higher socio-sustainability. However, 11 of the 12 respondents said, while PW does enhance the quality of road elsewhere, further research on technical performance of roads is required from an Auckland perspective. Three respondents raised concerns over PW melting under Auckland heat, and two of them also raised concerns over slipping (frictional), with M1 quoting, *"It needs the same slippery factor compared to the existing road, which is very high"*. Melting is an issue that Auckland roads are already witnessing, damaging vehicles and causing accidents (Newshub 2019).

Further, 90% of the respondents were worried about the toxic fumes arising before and after construction, which are unhealthy for the workers and community. Pollution of the air and water by microplastics was another issue that 60% respondents raised. Both worries have been supported by research studies (Popescu and Burlacu 2017; Awasthi,

Shivashankar, and Majumder 2017). But the respondents were optimistic about available solutions despite their worries. However, A1 argues that PW is safe during and after construction. A1 explains that fumes can be controlled during manufacturing processes and workers can use safety gears supplied by companies. Moreover, PW changes its form during construction as it gets melted with bitumen, becoming inert and incapable of creating microplastics or any gaseous fumes over the years, supported by Sasidharan, Torbaghan, and Burrow (2019). The respondents too were optimistic about available solutions despite their worries.

Lastly, all respondents agreed that easy and ready availability of PW reduces transportation time to sites or factories and 60% said that the processing time is also reduced, corroborated by studies (Ardalan, Wilson, and Larkin 2020). Thus, use of PW in roading results in the reduction of potential delays, relaxing society problems and resulting in enhanced socio-sustainability.

All respondents agree that PW has potential benefits to better the quality and performance of roads in Auckland as it enhances the quality of roads in other countries. Despite the benefits experienced by other countries, 11 of the 12 respondents are hesitant to confirm a clear view and they propose more scientific research with evidential approach towards performance of roads when using PW in Auckland. T2 quotes, *"If done without the proper research, it might affect the loading bearing capacity of the road"*. T1 adds, *"the summer comes, then perplexity growing; because of that we need excellent stable material on all normal temperature [sic]"*. This is a sharp contrast to the literature, which shows that plastic roads are much superior in quality, specially in similar Auckland-weather-like conditions in the UK (Matani 2020) or in places with hilly demographics as in India (Manju, Sathya, and Sheema 2017) and earthquake-prone Indonesia (Neo et al. 2021). Therefore, such concerns about PW affecting the quality and performance of Auckland roads that use PW leaves a grey area over its social sustainability even though it acts as a big solution for Auckland's plastic pollution – a social menace – in line with the theme of the Auckland perspective.

3.3. Environmental benefits

The first thought of PW is that of PW floating in water bodies and dumped on land. All respondents immediately agree that recycling PW in roading provides a good solution for Auckland's plastic pollution affecting the environment. Additionally, 10 respondents acknowledge that PW will not go to landfills but be recycled purposefully, benefitting the environment, as witnessed in the research of Chen et al. (2017), Kehinde et al. (2020) and Reed et al. (2021). Moreover, P2 explains that PW is chemically treated and changes its physical form during road construction processes. Consequently, it is not the same as that being pushed in landfills. However, two respondents

ring caution. M2 states, *“disposing of the PW will only be delayed further as they will first be utilised in the construction of roads and once the road is replaced or removed, this may end up in the landfill again”*, confirmed by the studies of Conlon (2021). But Brasileiro et al. (2019) and Sasidharan, Torbaghan, and Burrow (2019) contradict this view explaining that plastic roads can be recycled several times and used for smaller roads, leading to sustainable roading. Thus, using PW in roading is completely different from PW in landfills, offering better environmental benefit.

According to Awoyera and Adesina (2020), replacing bitumen with PW preserves non-renewable natural resources of bitumen, leading to good environmental sustainability. However, only three respondents (M1, M2 and A2) have acknowledged this vital factor.

Additionally, according to nine respondents, the purposeful use of PW is environment-friendly and reduces carbon emissions. Plămădeală and Plamadeala (2019) verify that production of traditional asphalt releases 96 million tonnes of CO₂ in the atmosphere, but plastic roads cut CO₂ emissions up to 72% compared to traditional roading. M2 explains that every volume of bitumen replaced saves equivalent amount of carbon emission, which otherwise is released while producing bitumen in refineries, as confirmed by Pouranian and Shishehbor (2019). Moreover, five other respondents agreed that carbon emissions can be saved indirectly as easy local availability of PW reduces transportation, saving fuel. However, WM1 and T3, being technical, were unsure about these aspects to comment and said that it depended on the technology used because PW may become harmful during roading processes. But A1 and P1 argued that new techniques using PW allow factory production and atmosphere-controlled construction, enabling green manufacturing and saving carbon emissions, as verified by Nishikant et al. (2016).

Additionally, 75% respondents had concerns over toxic fumes and microplastics produced by using PW but expressed confidence in new technologies to mitigate this issue. In fact, according to A1, using PW allows lower compaction temperatures during road construction, which produces lesser fumes compared to regular roading practices, verified by Chen et al. (2017). Further, A3 stated, *“I guess the advantages are much higher, and if you just think about the water so we treat our water system”*, for resolving microplastic-derived water pollution. Studies of Sasidharan, Torbaghan, and Burrow (2019) endorse that many countries have successfully mitigated pollution and microplastic issues to achieve higher environmental sustainability. The Annual Report of MacRebur (2021) supports such a view, as about 32 tonnes of carbon emissions are offset in constructing a 1.6 km, two-way road, comparable to 2.3 million plastic bags. Therefore, PW can save natural resources, limit poisonous fumes and reduce landfill and carbon emissions, as well as being recycled effectively in

roading, boosting the environmental sustainability of Auckland roading companies, aligning with the theme of environmental benefits of using PW.

3.4. Challenges in implementation of PW

Auckland roading is currently done conventionally using asphalt. WM1 states, *“now there is some availability, so initiatives are not being taken to switch”*, which shows that the authorities are not taking proactive steps. T3 supports saying that the authorities are *“very picky”*. All of the respondents are aware about other countries using PW. However, only two (WM1, T3) of them commented on PW being used in New Plymouth and Christchurch, cities within NZ itself. This shows that in spite of NZ experimenting with PW in roading, it is not being promoted by the authorities despite the plastic epidemic, and such denial poses a significant challenge in PW implementation for Auckland roading.

Additionally, nine of the 12 respondents complain that the industry is backward, with practitioners hesitant to accept new materials or technology. T1 reiterates, *“I don’t want to see new changes because the new changes, they have to change everything [sic]”*. Such views concur with the findings of Karimian et al. (2019) and according to them, the roading industry in NZ is resistant to technology change due to the lack of training resources or value for investment, similar to T3’s comments, *“big companies work for big profit and not for charity”*. Notably, T2 also stated, *“Depends on the company. If the changing is not too much or not very costly companies may use fast [sic]. Another thing is if Government makes some rules and policy to follow then the companies will use the new technology in Auckland”*. This reflects that the involvement of investment costs is an important criterion and again establishes the control of the Council over the industry. However, A1 is totally convinced that the technology is easy, and several options are available similar to the existing technology, with lower cost and improved results. Herez (2019) confirms such views as a plastic-modified asphalt mixture was stored at a work site for an extended period of 3 weeks without issues and enabled lower temperature requirements and faster construction without toxic fumes.

But, according to Plămădeală and Plamadeala (2019), the revolutionary technology of making prefabricated PW hollow modules used for building roads without asphalt requires serious investments. Thus, the technology for using PW and their investments reveal another challenge for the Auckland Council and the roading industry together.

Further, as discussed above, most of the respondents demand adequate research before implementing PW in Auckland as the life cycle of a road is 40–50 years. It is not logical to wait for such a long time for results, and alternative ways should be found, which is possible due to predictive technologies in modern times (Mungathia 2021). Additionally, there are ample

scientific experiments such as Marshall's tests, which prove the toughness of roads (Raheel et al. 2018), and research findings are available (White et al. 2019), which show enhanced quality and performance of PW roads compared to normal roads. Thus, challenges can be mitigated if innovative ideas and initiatives are taken up by the Council or roading companies.

However, A2 explains that there are only a couple of companies at the national level, which makes them complacent in enforcing innovative ideas. The other companies compete in the local and regional markets, which hinders innovation and productivity (Karimian et al. 2019). The explanations of A2 are confirmed in the New Zealand Sectors Report 2013 published by the Ministry of Business, Innovations and Employment (MBIE) (MBIE 2013), naming Fulton Hogan and Downer Group as the dominant infrastructure companies. They form barriers for competition by smaller companies that facilitate innovation such as introducing PW in roading and are able to quantify the production levels. The duopoly policy of the NZ Government creates a challenge as it would depend on these two companies to implement PW in their processes.

On the other hand, adopting sustainability practices by themselves comes at a price. For example, PPE gears in construction roading involve high costs (Griffiths, Boyle, and Henning 2018). Roading companies get flexible around these areas, as expressed by T1, *"so the price matter is the concern because people are doing big business for making a big profit, not charity"*. Ten of the 12 respondents agreed that companies want some kind of benefit or need to be forced out of some regulation for sustainable roading as there are costs involved for green roading (Pouranian and Shishehbor 2019), highlighting some challenges.

Finally, all the respondents agree that the implementation should be done fast. According to T1, the Council and Industry should stop thinking and start doing things in roading. Thus, 75% of the respondents explained that PW need not be used on the main highways but can be used on smaller rural or arterial roads, sidewalks and even drainages, where it is of low risk and can be monitored conveniently, similar to the situation in Australia (White 2020).

Thus, there are a few challenges to be met for using PW in Auckland roading, where the initiative of the Auckland Council is primary, with P1 reminding, *"the City Council is the main part. they might say no, we can't do it"*.

To summarise, PW use in roading increases the economic sustainability of the infrastructure companies in various ways and significantly improves the environmental sustainability for the roading industry. But there are a few doubts on the performance and quality of roads from the Auckland perspective. These doubts cast a shadow on the socio-sustainability of the roading sector despite the benefits exhibited by different countries and Auckland's plastic

plague, provided by sufficient evidence of the literature reviews. Additionally, the Auckland Council plays a vital role in the roading industry and can mitigate challenges in the implementation of PW in Auckland roading, conforming to the theme of the Auckland Council's role in roading.

4. Conclusion, Recommendations and Limitations

This section concludes the research paper with some recommendations and limitations of this research.

4.1. Conclusion and recommendations

This research has explored the use of PW in Auckland roading. The Auckland roading industry continually faces challenges in improving its sustainability. Factors may arise that may decrease its profits. Moreover, infrastructure companies face complaints of society disturbances and accidents, and these companies complain about environmental regulations clamping down their activities. Thus, there is a need to address their sustainability concerns. Additionally, Auckland's plastic pollution is only magnifying. On the other hand, many countries are already using PW beneficially. Diverse technologies with varying amounts of PW in different forms have been used and proven to be successful. This also shows that many countries are able to tackle their PW problems uniquely and fruitfully through roading. Auckland faces challenges of plastic pollution but does not use it in roading. This research attempts to put two negatives (sustainability challenges and plastic pollution) to make a positive.

Overall, this research finds the use of PW in Auckland roading beneficial to infrastructure companies, enhancing their sustainability. The infrastructure companies can profit directly by saving raw material and labour cost or indirectly by saving transportation cost and project time, boosting their economic sustainability. Thus, aptly answering the research Question 1 – How can the use of PW in Auckland Road construction improve economic sustainability? In addition, the companies can also attain social sustainability from the standpoint of reducing destructive PW from Auckland societies. Despite enough practical and scientific evidence from different countries provided by research studies, there is still an element of concern regarding the quality of roads, with the expert respondents recommending that the topic needs to be researched from the Auckland standpoint. The approach of using PW for Auckland must be cautionary considering social sustainability but the experts concede the fact that there are options available to reduce their concerns and that advantages far outweigh the shortcomings, thus, satisfactorily answering research Question 2 – How can the use of PW better the quality of Auckland roads and enhance social sustainability in Auckland? Further, the companies

can achieve higher environmental sustainability by using PW because lower amounts of toxic fumes are released and green manufacturing is possible, enabling reduction of carbon emission. Substitution of bitumen by PW conserves natural resources, hence, answering research Question 3 – How can the use of PW in the Auckland construction industry help environmental sustainability?

However, this research has revealed the control of the Auckland Council over the roading Industry. It is at the complete discretion of the Auckland Council to incorporate PW as a material in Auckland road construction. Although they always encourage innovative ideas in roading, PW has not been introduced. It is recommended that they accept and use PW in roading immediately to gain benefits like other countries. Some technologies are quite similar to conventional roading in Auckland, which are simple and easy to use. For instance, India is using a simple PW-shredding process infused with the bitumen mix (Sasidharan, Torbaghan, and Burrow 2019), which has also been used in NZ in New Plymouth. It is recommended that the Council become proactive in implementing such new technology rather than being satisfied using old techniques. Auckland must introduce PW immediately due to its simplicity. It is recommended for PW to be trialled on walking and cycling paths or on smaller arterial roads – a focus of the ATAP – which have low traffic pressure. These are low-risk areas as they can be effectively monitored and well managed, catering to the societal concerns, thus providing appropriate opportunities for trials. Since the ATAP 2021–2031 has a provision for \$742 million for using new materials and innovation, the Auckland Council can take inspiration from the UK Government, which has sanctioned £23 million for trial research regarding new polymerised asphalt and techniques for pothole repairs (Engineering and Technology 2019).

Apart from the simple technology for infusing PW, infrastructure companies can use radical technology for constructing cycling lanes or footpaths initially and later highways akin to the Netherlands to produce hollow plastic modules. The Auckland Council must boost these new initiatives with the help of waste management companies and roading companies. But introducing new technologies requires huge investments and can be a financial burden on infrastructure companies due to the involvement of new equipment and machinery (Amankwah-Amoah 2020). The NZ Government can give tax benefits in lieu of such investments or subsidise the equipment for new technology (Ravšelj and Aristovnik 2018), incentivising the companies, more importantly as NZ would consume its own PW, saving export costs and upholding its international green image.

Understanding the merits in the use of PW, the Ministry of Indian Transport has regularised and mandated the use of PW on national highways (Laskar and Kumar 2019) and experienced all benefits of PW. Similarly, the Auckland Council can mandate the use of PW in building roads. In this way, the

companies will be forced to use PW innovatively in several ways, which will help in breaking the duopolistic nature of the infrastructure industry, as seen in Section 3.4.

Infrastructure companies face continuous pressure to improve sustainability as they are regarded as high contributors to pollution (Kaluvarachchi et al. 2021). Considering the benefits discussed in Section 1.8 (Other countries using PW) and Section 3 (Results and Discussion), it is recommended that infrastructure companies coerce the Auckland Council for accepting PW in roading infrastructure companies. Infrastructure companies then will be able to source locally available PW instead of relying on imports of bitumen. This will resolve material shortage issues, reduce transport time, save costs for the company and save foreign exchange for NZ. Using PW will open new dimensions for using various technologies to enable faster construction, reducing labour costs and providing safety for workers and the environment, similar to Ghana making plastic-based pavement blocks in a factory (Sasidharan, Torbaghan, and Burrow 2019). Crucially, the companies can proclaim their involvement in reducing Auckland's plastic pollution, helping the community and the Council and thus improving their sustainability image.

Hence, the infrastructure companies, the Auckland Council and waste management companies can benefit simultaneously and assist each other if PW is used in roading. Auckland can achieve reduction in greenhouse gas emissions by 13% per capita, a target for decarbonising Auckland's transport system by 2040 (ATAP 2021–2031, 2021), in addition to implementation of the targets set by NZ for achieving several UNSDGs by 2030, especially five related to good health and well-being, 11 related to sustainable cities and communities, 13 related to climate action, 14 for issues related to below-water areas, and 15 related to life on land (UNSDG 2021). The companies can make low-cost, good-quality roads requiring low repair and maintenance, profiting themselves and the Council. Benefits from the roads can translate to lower road taxes and lesser fuel cost (Small, Winston, and Evans 2012), being profitable to society and the taxpayers, namely "you". Accordingly, this research can be useful for infrastructure companies, waste management companies, Governments and, yes, "you" too. The findings of this research contribute to information and knowledge of the challenges that the Auckland roading industry faces in ensuring its sustainability and how they can be enhanced by using PW.

Therefore, this research has shown that incorporating PW can resolve the economic, social and environmental challenges that Auckland road construction faces and also offer a purposeful solution for Auckland's plastic pollution, arriving at a win-win situation as it benefits everybody: the companies, the Auckland Council, people and, most importantly, the Earth, achieving a similar research objective. So why this is not being implemented in Auckland is concerning and calls for urgent attention from the Auckland Council and the NZ Government.

4.2. Limitations and suggestions for further studies

- This research is limited to Auckland only; research is recommended for other regions in NZ having different climates, and the effects of PW corresponding to specific parameters such as earthquakes can be studied.
- The research is limited to road construction only. Residential projects have already started using PW effectively.
- Further studies are recommended for footpaths and cycling paths specifically, which are currently the focus area of the Council.
- Research is recommended to use waste materials such as waste rubber and glass in roading, which cause sustainability issues. Research can be done for individual materials or when they are used in combination with each other. As suggested by T1, when rubber is incorporated in road or building construction, it acts as a good shock absorber, allowing more durability for the road structure.
- Finally, similar research can be carried out with inputs from the Auckland Council, since their role has been highlighted significantly.

References

- AA Motoring. 2021. "Petrol Tax." Accessed May 23, 2021. <https://www.aa.co.nz/cars/owning-a-car/fuel-prices-and-types/petrol/>
- Adkin, L. E. 2018. "1. Ecology and Governance in a First World Petro-State." In *First World Petro-Politics*, edited by Laurie E. Adkin. 3–50. Canada: University of Toronto Press.
- Amankwah-Amoah, J. 2020. Stepping up and Stepping Out of COVID-19: New Challenges for Environmental Sustainability Policies in the Global Airline Industry. *Journal of Cleaner Production* 271: 123000.
- Ardalan, N., D. J. Wilson, and T. J. Larkin. 2020. Analyzing the Application of Different Sources of Recycled Concrete Aggregate for Road Construction. *Transportation Research Record* 2674 (8): 300–8.
- Armat, M. R.; A. Assarroudi, M. Rad, H. Sharifi, and A. Heydari. 2018. Inductive and Deductive: Ambiguous Labels in Qualitative Content Analysis. *The Qualitative Report*, 23 (1): 219–21.
- AT Code of Practice. 2013. "Auckland Transport Code of Practice." Accessed May 23, 2021. https://at.govt.nz/media/310152/Section_16_Road_Pavements_and_Surfacings.pdf
- AT. 2016, December. "Quality of Service Evaluation Tool for Cycle Facilities." Accessed June 07, 2021. <https://at.govt.nz/about-us/manuals-guidelines/quality-of-service-evaluation-tool-for-cycle-facilities/>
- AT. 2021. "Regional Fuel Tax." Accessed April 10, 2021. <https://at.govt.nz/about-us/our-role-organisation/corporate-plans-strategies/regional-fuel-tax/>
- ATAP 2021-2031. 2021. "Auckland Transport Alignment Project 2021 – 2031 Investment Programme." Accessed June 07, 2021. <https://www.transport.govt.nz/assets/Uploads/Report/ATAP20212031.pdf>
- Auckland Council. 2019 July. "Construction Water Management, Technical Report." Accessed June 07, 2021. <https://www.aucklandcouncil.govt.nz/UnitaryPlanDocuments/nor-wwm-05-construction-water-report.pdf>
- Auckland Council. 2021a. "10-Year Budget 2021/2031 Regional Organisations." Accessed June 07, 2021. <https://www.aucklandcouncil.govt.nz/have-your-say/topics-you-can-have-your-say-on/the-10-year-budget-2021-2031-long-term-plan-consultation/regional-organisations/regional-organisation-written-feedback-vol-10.pdf>
- Auckland Council. 2021b, June 3. "Planning Committee- Open Agenda." Accessed May 10, 2021. https://infocouncil.aucklandcouncil.govt.nz/Open/2021/06/PLA_20210603_AGN_10175_AT.htm
- Auckland Design Manual. 2016. "Erosion and Sediment Control Guide for Land, Disturbing Activities in the Auckland Region." Accessed April 10, 2021. <http://content.aucklanddesignmanual.co.nz/regulations/technical-guidance/Documents/GD05%20Erosion%20and%20Sediment%20Control.pdf>
- Auckland Transport. 2021a. "Auckland Transport Alignment Project 2021 – 2031 Investment Programme." Accessed June 07, 2021. <https://www.transport.govt.nz/assets/Uploads/Report/ATAP20212031.pdf>
- Auckland Transport. 2021b. "Projects Roadworks Eastern Busway Project Updates Impacts to Traffic." Accessed May 10, 2021. <https://at.govt.nz/projects-roadworks/eastern-busway/project-updates-impacts-to-traffic/>
- Awasthi, A. K., M. Shivashankar, and S. Majumder. 2017, November. Plastic Solid Waste Utilization Technologies: A Review. In *IOP Conference Series, London, UK.: Materials Science and Engineering*, Vol. 263, No. 2, 022024. IOP Publishing.
- Awoyera, P. O., and A. Adesina. 2020. Plastic Wastes to Construction Products: Status, Limitations and Future Perspective. *Case Studies in Construction Materials* 12: e00330.
- BBC. 2021, March 3. "Could Plastic Roads Make for a Smoother Ride?" Accessed May 20, 2021. <https://www.bbc.com/future/article/20210302-could-plastic-roads-make-for-a-smoother-ride>
- Belayutham, S., V. A. Gonzalez, and T. W. Yiu. 2016. A Cleaner Production-Pollution Prevention Based Framework for Construction Site Induced Water Pollution. *Journal of Cleaner Production* 135, 1363–78.
- Blom, C. M., and Guthrie, P. M. 2018. December. Infrastructure Outcomes: What New Project Operational Expenditure Reveals as Missing. *Proceedings of the Institution of Civil Engineers-Municipal Engineer* 171 (4): 216–33.
- Boyle, C. 2014. "Greening Cities: A Review of Green Infrastructure." Transforming Cities." Accessed August 10, 2021. <https://www.transformingcities.org.uk/wp-content/uploads/2014/11/Greening-Cities-A-Review-of-Green-Infrastructure.pdf>
- Brasileiro, L., F. Moreno-Navarro, R. Tauste-Martínez, J. Matos, and M. D. C. Rubio-Gámez. 2019. Reclaimed Polymers as Asphalt

- Binder Modifiers for more Sustainable Roads: A Review. *Sustainability* 11 (3): 646.
- Brown, K., and R. Visser. 2018. Adoption of Emergent Technology for Forest Road Management in New Zealand. *New Zealand Journal of Forestry Science* 63 (3): 23–9.
- Business Govt.NZ. 2021. "How to be Environmentally Sustainable." Accessed April 10, 2021. <https://www.business.govt.nz/getting-started/business-planning-tools-and-tips/how-to-be-environmentally-sustainable/>
- Chen, J., F. Zhao, Z. Liu, X. Ou, and H. Hao. 2017. Greenhouse Gas Emissions from Road Construction in China: A Province-Level Analysis. *Journal of Cleaner Production* 168, 1039–47.
- Conlon, K. 2021. Plastic Roads: Not All They're Paved Up to Be. *International Journal of Sustainable Development & World Ecology*, 29 (1) 80–83.
- De Bhowmick, G., A. K. Sarmah, and B. Dubey. 2021. Microplastics in the NZ Environment: Current Status and Future Directions. *Case Studies in Chemical and Environmental Engineering* 3, 100076.
- Employment NZ. 2021. "How Much to Pay and Pay Rises." Accessed May 3, 2021. <https://www.employment.govt.nz/hours-and-wages/pay/how-much-to-pay/>
- Engineering and Technology. 2019. "Plastic Road Trials Expanded by UK Government." Accessed April 10, 2021. <https://eandt.theiet.org/content/articles/2019/01/plastic-road-trials-expanded-by-uk-government-to-stop-potholes/>
- Etikan, I., S. A. Musa, and R. S. Alkassim. 2016. Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics* 5 (1): 1–4.
- Evans, C., and J. Lewis. 2018. *Analysing Semi-Structured Interviews Using Thematic Analysis: Exploring Voluntary Civic Participation Among Adults*, 1–6. UK: Sage Publications Limited.
- Fischer, J. M. 2020. Handling Waste through Consensus, Care and Community in Auckland, Aotearoa New Zealand. *Urban Ethics: Conflicts Over the Good and Proper Life in Cities*.
- Gerrard, J. 2020. "Annual Report 2020." Mahi Tahī 2.
- Ghaljaie, F., M. Naderifar, and H. Goli. 2017. "Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research." *Strides in Development of Medical Education* 14 (3).
- Greater Auckland. 2018, May 17. "Auckland's Appalling Road Safety Reasons Laid Out." Accessed June 04, 2021. <https://www.greater-auckland.org.nz/2018/05/17/aucklands-appalling-road-safety/>
- Greater Auckland. 2020, September 9. "Truckers: Fix the Road." Accessed May 12, 2021. <https://www.greeterauckland.org.nz/2020/09/09/fixing-the-roads/>
- Greater Auckland. 2021, January 13. "Recent Road Safety Discussions." Accessed April 10, 2021. <https://www.greeterauckland.org.nz/2021/01/13/recent-road-safety-discussions/>
- Greater Auckland. 2021, May 19. "The Challenges of Working in the Road Corridor." Accessed August 2021. <https://www.greeterauckland.org.nz/2021/05/19/the-challenges-of-working-in-the-road-corridor/>
- Griffiths, K., C. Boyle, and T. F. Henning 2018. "Beyond the Certification Badge – How Infrastructure Sustainability Rating Tools Impact on Individual, Organizational, and Industry Practice." *Sustainability* 10 (4): 1038.
- Hall, F., and G. White. 2021. "Using Local Waste Plastics in Asphalt Modification to Improve Engineering Properties of Roads." In Proceedings of the 36th International Conference on Solid Waste Technology and Management. Annapolis, Maryland, USA. 2021.
- Hall, F., & White, G. (2021). Using Local Waste Plastics in Asphalt Modification to Improve Engineering Properties of Roads. *Journal of Materials in Civil Engineering* 33 (4), 04021008. doi: 10.1061/(ASCE)MT.1943-5533.0003656
- Hammarberg, K., M. Kirkman, and S. de Lacey. 2016. Qualitative Research Methods: When to Use them and How to Judge Them. *Human Reproduction* 31 (3): 498–501.
- Harker, J., P. Taylor, and S. Knight-Lenihan. 2017. Multi-Level Governance and Climate Change Mitigation in New Zealand: Lost Opportunities. *Climate Policy* 17 (4): 485–500.
- Herez, M. H. 2019. *Development of A New High Performance Cold Mix Asphalt*. United Kingdom: Liverpool John Moores University.
- Imran, M., and L. Matthews. 2011. "Discursive Path Dependence: Keeping the Supremacy of Road-Based Urban Transport Planning in Auckland." *Road & Transport Research: A Journal of Australian and New Zealand Research and Practice* 20 (1): 41.
- Kaluvarachchi, M., A. Waidyasekara, R. Rameezdeen, and N. Chileshe. 2021. Mitigating Dust Pollution from Construction Activities: A Behavioural Control Perspective. *Sustainability* 13 (16): 9005.
- Karimian, S. H., J. Mbachu, T. Egbelakin, and W. Shahzad. 2019. "Improving Efficiency in Roading Projects: A New Zealand Study." *Engineering, Construction and Architectural Management* 26 (5): 827–849.
- Kehinde, O., O. J. Ramonu, K. O. Babaremu, and L. D. Justin. 2020. Plastic Wastes: Environmental Hazard and Instrument for Wealth Creation in Nigeria. *Heliyon* 6 (10): e05131.
- Khati, R., and C. A. Boyle 1999. Use of Waste Materials in Road Construction in New Zealand. In *Australasian Environmental Engineering Conference: Engineers Deliver Sustainability*, Sydney. July 1999.
- Kiger, M. E., and L. Varpio. 2020. "Thematic Analysis of Qualitative Data: AMEE Guide No. 131." *Medical Teacher* 42 (8): 846–54.
- Kivilä, J., M. Martinsuo, and L. Vuorinen. 2017. Sustainable Project Management through Project Control in Infrastructure Projects. *International Journal of Project Management* 35 (6): 1167–83.
- Klaeger, G. 2013. Dwelling on the Road: Routines, Rituals and Roadblocks in Southern Ghana. *Africa* 83 (3): 446–69.
- Kumar, R. 2018. *Research Methodology: A Step-by-Step Guide for Beginners*. Thousand Oaks: Sage.
- Laskar, N., and U. Kumar. 2019. Plastics and Microplastics: A Threat to Environment. *Environmental Technology & Innovation* 14, 100352.
- Lessing, B., D. Thurnell, and S. Durdyev. 2017. Main Factors Causing Delays in Large Construction Projects: Evidence from New Zealand. *Journal of Management, Economics and Industrial Organization* 1 (2): 63–82.
- Leung, C., Destremau, K., Pambudi, D., & Bealing, M. (2017). Benefits from Auckland Road Decongestion. Accessed June

- 04, 2023. <https://www.nzta.govt.nz/assets/resources/research/reports/617-617.pdf>
- Macrebur. 2021. "Media." Accessed June 25, 2021. <https://macrebur.com/media>
- Manju, R., S. Sathya, and K. Sheema. 2017. Use of Plastic Waste in Bituminous Pavement. *International Journal of ChemTech Research* 10 (8): 804–11.
- Matani, A. G. 2020. "Plastic Waste in Construction and Road Making." *The Prime Minister at the United Nations General Assembly* 64 (1): 56.
- MBIE. 2013. "The New Zealand Sectors Report 2013 Featured Sector: Construction." Accessed June 04, 2023. <https://www.mbie.govt.nz/assets/77439ddc45/Construction-report-2013.pdf>
- Muleya, F., B. Mulenga, S. L. Zulu, S. Nwaubani, C. K. Tembo, and H. Mushota. 2020. Investigating the suitability and cost-benefit of copper tailings as partial replacement of sand in concrete in Zambia: An exploratory study. *Journal of Engineering, Design and Technology* 19 (4): 828–849.
- Mungathia, M. T. 2021. "Performance Predictive Model for Sisal-Plastic Modified Asphalt Concrete for Road Pavement." Doctoral dissertation, JKUAT-COETEC.
- Neaylon, K. L., L. C. van den Kerkhof, J. P. Wu, P. R. Herrington, T. F. P. Henning, D., Rogers, P. Karan, et al. 2019. *Performance Benefits of Polymer Modified Bitumen Binders for Thin Surfacing*, No. 655.
- Neo, E. R. K., G. C. Y. Soo, D. Z. L. Tan, K. Cady, K. T. Tong, and J. S. C. Low. 2021. Life Cycle Assessment of Plastic Waste End-of-Life for India and Indonesia. *Resources, Conservation and Recycling* 174:, 105774.
- Neuendorf, K. A. 2018. Content Analysis and Thematic Analysis. In *Advanced Research Methods for Applied Psychology*, 211–23. Routledge.
- Newman, P., K. C. Hargroves, C. Desha, L. Whistler, A. Farr, K. Wilson, K., and Surawski, L. 2012. Reducing the environmental impact of road construction. Accessed June 04, 2023. <https://eprints.qut.edu.au/85967/>
- Newshub, 2019, January 11, "NZTA Apologises after Melting Roads Coat Cars in Bitumen." Accessed May 3, 2021. <https://www.newshub.co.nz/home/new-zealand/2019/01/nzta-apologises-after-melting-roads-coat-cars-in-bitumen.html>.
- Nishikant, K., A. Nachiket, I. Avadhut, and A. Sangar. 2016. Manufacturing of Concrete Paving Block By Using Waste Glass Material. *International Journal of Scientific and Research Publications* 6 (6): 61–77.
- NZ Herald. 2019, April 9, "NZ's Green Image Let Down by its Huge Plastic Waste Consumption: Study." Accessed April 17, 2021. <https://www.nzherald.co.nz/nz/nzs-green-image-let-down-by-its-huge-plastic-waste-consumption-study/O55XTCEWITX3JKP-BRUWLQEWAIU/>.
- NZ Transport Agency (NZTA), 2019, November. "Bitumen Cost Adjustment Series Change." Accessed June 04, 2021. <https://www.nzta.govt.nz/assets/resources/general-circulars/docs/19-04.pdf>
- NZTA Road Pavements. 2021. "Choosing the Right Pavement for the Traffic." Accessed May 23, 2021. <https://www.nzta.govt.nz/roads-and-rail/road-composition/road-pavements/>.
- NZTA. 2018. "New Zealand Guide to Pavement Structural Design." Accessed April 17, 2021. <https://www.nzta.govt.nz/roads-and-rail/road-composition/road-pavements/>.
- NZTA. 2021. "Standard, Guidelines and Specifications." Accessed May 23, 2021. <https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/urban-design-and-landscaping/standards-guidelines-and-specifications/>.
- Omisakin, O., and J. Roy. 2018. Recycling of Beverage Containers in New Zealand: Critical Analysis of Existing Status and Proposed Best Practices. *International Journal of Waste Resources*. 8 (3): 2–6.
- Parrangan, P., R. Rachman, and J. Tanijaya. 2021. "Study Delay of Road and Bridge Construction Project in Yalimo Regency, Papua Province." *International Journal of Innovative Science, Engineering & Technology* 8 (8): 650–8.
- Plămădeală, V., and A. Plamadeala. 2019. "The Roads of the Future." *Journal of Engineering Science* 26 (2): 22–34.
- Popescu, D., and A. Burlacu. 2017. Considerations on the Benefits of Using Recyclable Materials for Road Construction. *Romanian Journal of Transport Infrastructure* 6 (1): 43–53.
- Pouranian, M. R., and M. Shishehbor. 2019. Sustainability Assessment of Green Asphalt Mixtures: A Review. *Environments* 6 (6): 73.
- Raheel Shah, S. A., H. Arshad, A. Waqar, M. H. Saeed, S. Hafeez, J. Mansoor, J., A. N. Sadiq, et al. 2018. Saving Energy in the Transportation Sector: An Analysis of Modified Bitumen Application Based on Marshall Test. *Energies* 11 (11): 3025.
- Rahi, S. 2017. Research Design and Methods: A Systematic Review of Research Paradigms, Sampling Issues and Instruments Development. *International Journal of Economics & Management Sciences* 6 (2): 1–5.141. Institution of Professional Engineers New Zealand.
- Ravšelj, D., and A. Aristovnik. 2018. The Impact of Private Research and Development Expenditures and Tax Incentives on Sustainable Corporate Growth in Selected OECD Countries. *Sustainability* 10 (7): 2304.
- Reed, C., T. Fisher, A. Burgess, and T. Denne. 2021. Understanding the Value of Meeting the Requirements of Environmental Legislation for Road Improvement Projects 6HSWHPEHU.
- RNZ. 2019, September 24. "Crunch Time' for NZ's Quarries as Aggregate Price Soar." Accessed May 3, 2021. <https://www.rnz.co.nz/news/national/399508/crunch-time-for-nz-s-quarries-as-aggregate-price-soar>.
- Rosalyn, M. E., and D. Kurniawan. 2019. A Solution to Plastic Problems; A Stronger Campaign Or An Innovative Waste Management. *Jurnal Kajian Media* 3 (1).
- Roulston, K., and M. Choi. 2018. Qualitative interviews. *The SAGE Handbook of Qualitative Data Collection*, 233–49. SAGE Publications.
- Sasidharan, M., M. Eskandari Torbaghan, and M. P. N. Burrow. 2019. Using Waste Plastics in Road Construction. K4D Helpdesk Report. Brighton, UK.

- Small, K. A., C. Winston, and C. A., Evans. 2012. *Road Work: A New Highway Pricing and Investment Policy.* Washington D.C. Brookings Institution Press.
- Sorvig, K., and J. W. Thompson. 2018. *Sustainable Landscape Construction: A Guide to Green Building Outdoors.* Washington, DC: Island Press.
- Steyn, W., I. Holleran, and B. Nam. (eds.). 2018. "Pavement Materials and Associated Geotechnical Aspects of Civil Infrastructures." In *Proceedings of the 5th GeoChina International Conference 2018 – Civil Infrastructures Confronting Severe Weathers and Climate Changes: From Failure to Sustainability*, July 23–25, 2018, HangZhou, China. Springer.
- Stuff. 2018, January 10. "Pothole Damage to Cars Triggers Compensation Requests to Auckland Transport." Accessed April 17, 2021. <https://www.stuff.co.nz/auckland/local-news/central-leader/100437494/pothole-damage-to-cars-triggers-compensation-requests-to-auckland-transport>.
- Stuff. 2019a, July 18. "NZ Turns in Development Report Card to UN, Emphasising Wellbeing Framework." Accessed May 12, 2021. <https://www.stuff.co.nz/national/politics/114321259/nz-turns-in-development-report-card-to-un-emphasising-wellbeing-framework>
- Stuff. 2019b, July 30. "Road Building Delayed Because Governments 'Fail to Plan for Quarries.'" Accessed August 18, 2021. <https://www.stuff.co.nz/business/122277548/road-building-delayed-because-governments-fail-to-plan-for-quarries>.
- Stuff. 2020a, December 12. "Cost Blowouts on 17 Roads Cost NZTA \$1.1 Billion." Accessed May 12, 2021. <https://www.stuff.co.nz/national/politics/300181872/cost-blowouts-on-17-roads-cost-nzta-11-billion>
- Stuff. 2020b, November 1. "Roading Industry Confident it can Rely on Imported Bitumen." Accessed April 17, 2021. <https://www.stuff.co.nz/business/123215155/roading-industry-confident-it-can-rely-on-imported-bitumen>.
- Stuff. 2020c, September 25. "Auckland's Dome Valley Dump Plans 'Should be Refused'. Over Environmental Concerns." Accessed July 18, 2021. <https://www.stuff.co.nz/environment/300116508/aucklands-dome-valley-dump-plans-should-be-refused-over-environmental-concerns>.
- Stuff. 2021, April 20. "Transport Spending is Crucial, but We Must Make Sure We Pick the Right Project." Accessed May 12, 2021. <https://www.stuff.co.nz/business/transforming-business/124863914/transport-spending-is-crucial-but-we-must-make-sure-we-pick-the-right-projects>
- Tulashie, S. K., E. K. Boadu, F. Kotoka, and D. Mensah. 2020. "Plastic Wastes to Pavement Blocks: A Significant Alternative Way to Reducing Plastic Wastes Generation and Accumulation in Ghana." *Construction and Building Materials* 241: 118044.
- TVNZ. 2021a, June 4. "Major Cost Blowouts Put Multiple Transport Projects on Backburner." Accessed August 17, 2021. <https://www.tvnz.co.nz/one-news/new-zealand/major-cost-blowouts-put-multiple-transport-projects-backburner>
- TVNZ. 2021b, May 29. "New Zealand's Recycling Still Being Shipped to Countries Like Malaysia, Thailand." Accessed July 3, 2021. <https://www.tvnz.co.nz/one-news/new-zealand/new-zealands-recycling-still-being-shipped-countries-like-malaysia-thailand>.
- UNSDG. 2021. "Sustainable Development Goals." Accessed July 18, 2021. <https://unsdg.un.org/>.
- Velenturf, A. P., and J. S. Jopson. 2019. "Making the Business Case for Resource Recovery." *Science of the Total Environment* 648: 1031–41.
- Walker, D. B., D. J. Baumgartner, C. P. Gerba, and K. Fitzsimmons. 2019. "Surface Water Pollution." In *Environmental and Pollution Science*, 261–292. Academic Press.
- White, G. 2019, February. "Evaluating Recycled Waste Plastic Modification and Extension of Bituminous Binder for Asphalt." In *Eighteenth Annual International Conference on Pavement Engineering, Asphalt Technology and Infrastructure*, Liverpool, England, United Kingdom.
- White, G. 2020. A Synthesis on the Effects of Two Commercial Recycled Plastics on the Properties of Bitumen and Asphalt. *Sustainability* 12 (20): 8594.
- Wiik, M. K., C. Flyen, S. M. Fufa, and C. Venås. 2020, November. "Lessons Learnt From Green Public Procurement in the Norwegian Construction Sector." In *IOP Conference Series: Earth and Environmental Science* 588 (2): 022017. IOP Publishing.
- Williams, L. 2018. "End of the Asphalt Road?" *Engineering & Technology* 13 (9): 72–3.
- Williams, M., and T. Moser 2019. "The Art of Coding and Thematic Exploration in Qualitative Research." *International Management Review* 15 (1): 45–55. "An exploratory study." *Journal of Engineering, Design and Technology*. (Similar Explorative Study Used Replacing).
- Wu, S., and L. Montalvo. 2020. "Repurposing Waste Plastics into Cleaner Asphalt Pavement Materials: A Critical Literature Review." *Journal of Cleaner Production*, 124355.
- Xie, S., P. Crimmins, J. L. Metcalfe, S. Sridhar, L. Wickham, and S. Peeters. 2019. *Auckland Air Emissions Inventory 2016*. Auckland Council, Te Kaunihera o Tāmaki Makaurau.
- Yacob, P., L. S. Wong, and S. C. Khor. 2019. "An Empirical Investigation of Green Initiatives and Environmental Sustainability for Manufacturing SMEs." *Journal of Manufacturing Technology Management* 30 (1): 2–25.
- Yale Environment 360 Magazine*. 2021, February 11. "How Paving with Plastic Could Make a Dent in the Global Waste Problem." Accessed May 23, 2021. <https://e360.yale.edu/features/how-paving-with-plastic-could-make-a-dent-in-the-global-waste-problem>.