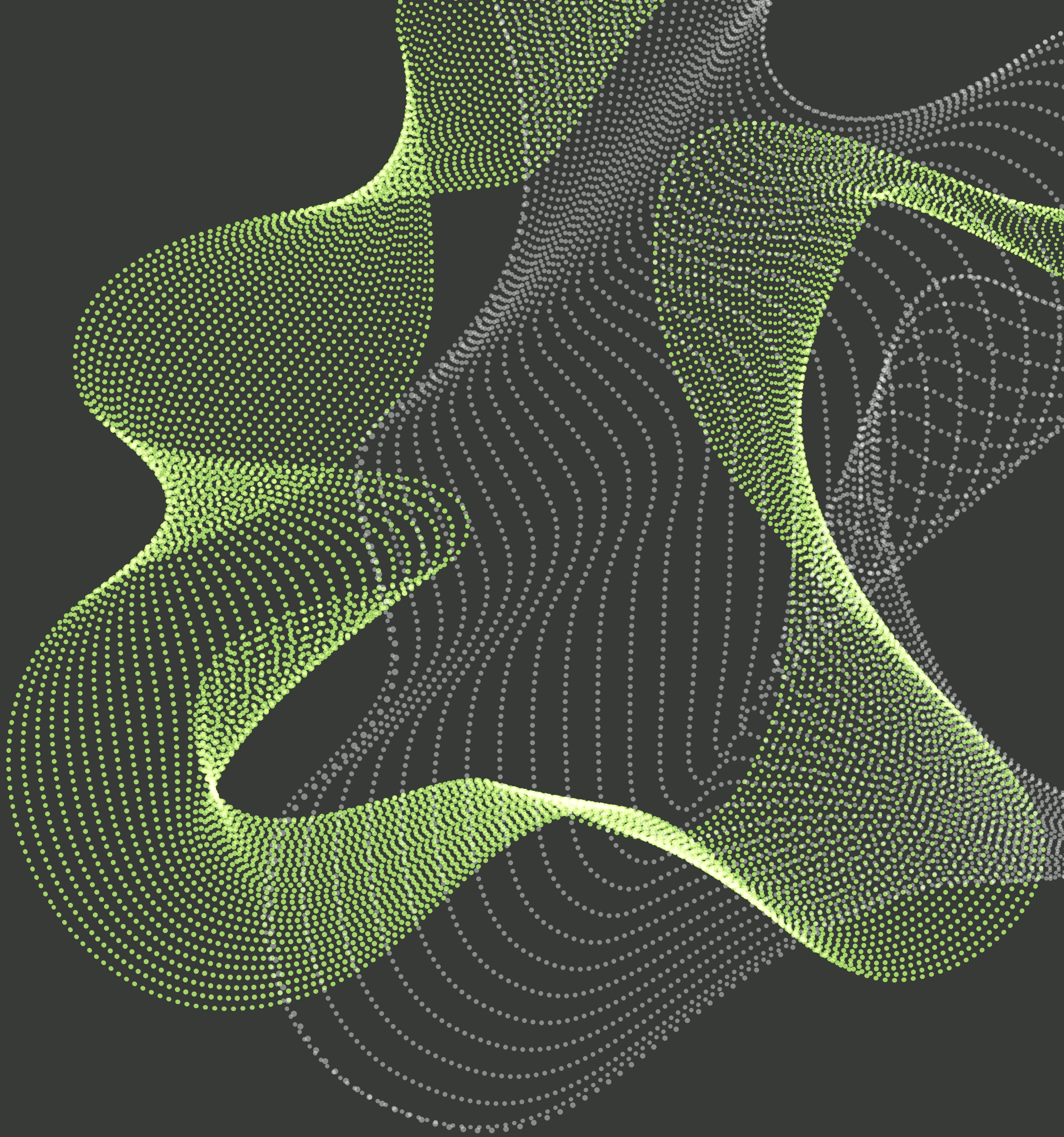

Redesign the Road

Blair Monk

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A major component of the Aurecon Design Academy is the individual project-based research paper. The research involved developing technical innovation and application methods for an actual project through experimentation, prototyping and human-centred design. This research paper is the result of such a project and authored by an Aurecon Design Academy graduate.

All Aurecon Design Academy research papers are developed with the support of academics from the Royal Melbourne Institute of Technology (RMIT). However, all Aurecon Design Academy research papers reflect the author's independent views. Further, Aurecon Design Academy research papers are not commissioned or paid for by any organisation, government, or other institution, and are not intended to promote the interests of Aurecon's clients.

About Aurecon Design Academy

Aurecon Design Academy is Aurecon's flagship learning program for technical mastery.

Formalised by RMIT University into a Graduate Certificate in Design Management, Aurecon Design Academy aims to foster eminence and a human-centred, transdisciplinary approach to design problems, enabling us to serve clients through design excellence and innovation.

It is a three-year program delivered via a mix of face-to-face, virtual and remote learning and includes both team and individual assignments and assessments. For those who successfully complete all course requirements, the program culminates in a graduation ceremony held in recognition of their achievements. Entry to the Design Academy is by a competitive application process and takes place annually and those that are accepted to the program are known as Design Scholars.

Following a blended approach with sessions delivered by a combination of Aurecon leaders, renowned academics, and external facilitators, combined with application activities deployed on projects, it aims to develop mastery amongst senior design and advisory practitioners.

Its purpose is to elevate technical mastery at Aurecon to the highest level enabling us to better serve our clients, through design excellence and innovation. Technical mastery is a key principle and core value creator at Aurecon and as such, the Design Academy sets out to help learners develop skills to elevate the value they can offer our clients.

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Abstract and Introduction

1 Abstract

1.1 Abstract

This paper proposes to redesign the road cross section to accommodate the new Micromobility transport modes. However, it does not just state that space should be made available, it proposes reimagining the use of road space into a speed flow continuum, that is not transport mode specific:

- Left slow
- Right fast
- Move between lanes depending on your speed, not the mode of vehicle being used
- Consider the user's needs and look to nature for alternative designs
- Change the laws to reflect the change from **vehicle form** to **transport function**
- Redesign our road cross section to solve this wicked problem

This study reviews recent rapid changes in transport modes and disruptive technologies that are impacting our urban environment. The uptake of Micromobility was not anticipated and is not well catered for in the current car-dominated transport system and streetscapes. This paper looks at the change in transport modes coming to our cities and recommends a shift in road design and the allocation of space to deal with mobility into the future.

Where this paper differs from others is that 'Design Led Thinking' has been used to propose a new way of accommodating and defining transport groups. The paper defines transport into function rather than form i.e., ***"it is not what you use to transport yourself but how you use it."***

Further research post-Covid-19 lockdown is required to determine, in more detail, the spatial requirements and separation criteria that are appropriate for redesigning the new road layouts.

Additional future research should also be undertaken into how autonomous drones and other devices should be added into the road space, as the technologies develop.

2 Introduction

Micromobility is becoming a large digital disruptor to the traditional transport system.

The months of lockdown in 2020 pushed the world into a new digital age with a requirement for flexibility and new radical design-led thinking. Transport should not be immune to this change.

The author has a vision of the redesigned transport network, where the change in modes of transport is reflected in the change to the design of our roads and streets.

In the beginning of roads

3 In the beginning of roads

In the beginning of roads, there were people gathering for markets, transporting goods and generally moving between places. The need to move past each other was done at a slow pace and people could adjust to accommodate each other. As time moved on, roads became more of a thoroughfare with horse riders dominating the trading routes. This is thought to be the period when traveling on the left-hand side of the road was first introduced in many regions. It became the norm in the British empire because it allowed horse riders to move past each other in a predictable manner. This standard approach meant riders did not hit each other or the approaching horse with their scabbard, which was worn on the left.[ref: https://www.worldstandards.eu/cars/driving-on-the-left/]

There are also explanations about how and why some of the world changed in the 19th and 20th centuries and ended up driving on the right-hand side of the road. Those include Napoleon and bullock trains in the US western states, but they are another story not covered here.

The facts that matter are that the use of roads became predictable, safer and more efficient when accepted etiquette became the norm. This is still the case for drivers the world over, even in countries that do not have official driving licences such as Vanuatu. Predictable social norms still happen today, and the road rules facilitate this by making what other drivers are likely to do, clear to other road users. We can travel further faster and safer because we can predict what other drivers are going to do and adjust our driving to suit.

Over time, vehicles have changed to be faster and more dangerous to pedestrians. The early Roman cities dealt with the need for separation of horses and people by creating some of the first footpaths.

This separation continues today in cities all over the world. People, cyclists, cars, buses and other vehicles are separated based on **what** they are: A clearly defined vehicle classification, which is commonly called the **mode** of transport.

Figure 3-1: Ancient Roman street in Pompeii, Italy

3.1 Urbanisation

In 1950, 751 million people were said to live in urban areas, which was 30% of the world's population [Ref chapter 4, Global Attitudes & Trends 30/01/2014, Pew Research Centre]. In 2018, this number had grown to 4.2 billion living in cities around the world, comprising 55% of the world's population. The UN expects this trend to continue with 68% of the world's population of over 10 billion living in urban areas by 2050. [Ref UN, Department of Economic and Social Affairs, 2018 Revision of world Urbanization Prospects]

Infrastructure in many cities has struggled to keep pace with the increase in growth of the urban environment. Transport has been one of the big losers with the average vehicle travel speeds dropping in some cities to levels where using a car is only marginally viable.

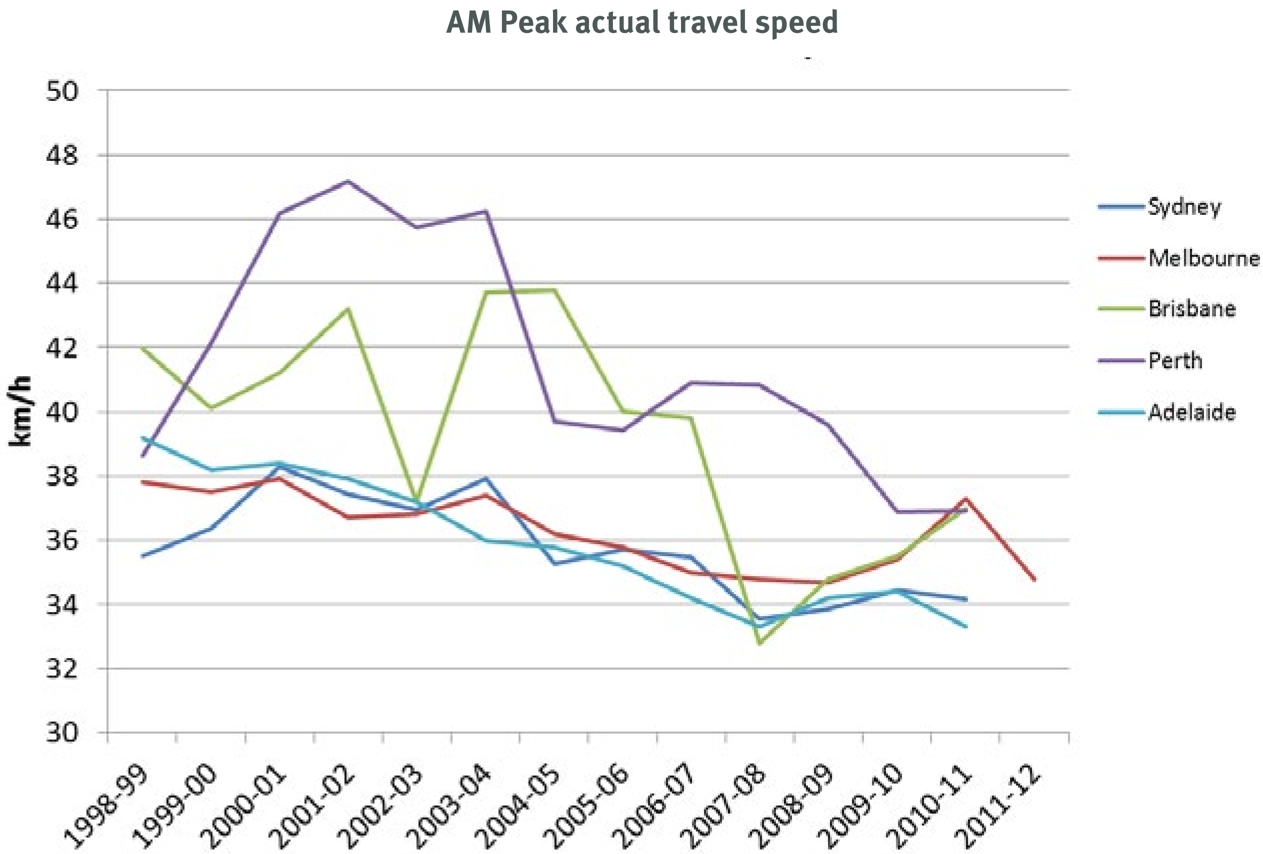

Figure 3-2: Trend in on road travel speeds for Australian cities [ref:https://chartingtransport.com/2010/10/31/trends-in-melbourne-traffic]

We have congestion in urban centres, but we still need to deliver people and goods for economic, education, health, leisure and other purposes.

More recently, Urban Designers and Transport Engineers have been trying to create separate spaces for well-defined modes of transport. Consequently, work is then needed to encourage people to use those particular modes.

This means many mass rapid transit systems are being built, along with bus lanes and cycle lanes being installed on streets where general traffic lanes once were.

Changing the space available for specific types of vehicles and limiting the routes people can take, has caused issues for some communities and businesses.

When bigger thinking of the whole ecosystem is brought into play, the results can be quite different. London, for example, had radial rail lines built by private rail companies. The rail companies also bought land adjacent to the rail lines. This created housing and available workforces for the Greater London business districts.

[Ref: Edwards, Dennis; Pigram, Ron (1988). The Golden Years of the Metropolitan Railway and the Metro-land Dream.]

As urbanisation continues, less people can afford to live near the public transit spines and public transit accessibility has not kept pace with urbanisation. This results in more people needing to use cars or other modes of transport to continue to access jobs.

This new demographic conflicts with the desire to force people from cars into other modes of travel. Many existing roads only have allocated space for pedestrians and motor vehicles. This creates a binary mode state.

3.2 The binary issue

The issue arises when the mode of transport does not fit this binary state of pedestrians on the footpath and motor vehicles on the road. Bicycles have long been an issue. Too fast for safe use on the footpath but, as a vulnerable transport mode, not well suited to roads, which have been designed for high powered cars, trucks and buses.

During the last three decades, the migration of people to bigger and more densely populated cities has brought into question these transport mode options that are polar opposites. [Ref: Accessible Streets Consultation 2020, Ministry of Transport and Waka Kotahi NZ Transport Agency.]

Bus lanes have started springing up to move more people faster over longer distances. While cycle lanes have been squeezed into the existing road footprint in an attempt to deal with the conflict and safety issues of this vulnerable mode.

Figure 3-3: Photo 'Marking something on a road, does not make it real!' Location St Lukes, Auckland

3.3 The growth of Micromobility

Bicycles, push scooters and skateboards have been around for a long time, but the advent of small powerful electric motors and rechargeable lithium batteries has seen an increase in invention and adaption to Micromobility.

In recent times, new electric-bicycles, electric-scooters and other new forms of Micromobility transport have been created and introduced into this urban landscape.

A study by Deloitte stated the demand for urban passenger-miles across all types of transport could double between 2015 and 2050.

[Ref: https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/micro-mobility- is-the-future-of-urban-transportation.html]

While mass transit remains the most efficient means of moving large volumes of people long distances, getting people to and from mass transit remains a perennial difficulty. If people lack a convenient, affordable way to get on a bus or train, then they are far more likely to opt for travel by car. This results in congestion and environmental effects or no travel at all.

People are therefore forgoing job opportunities, access to good food and medical care. Micromobility offers a tantalising solution to this issue.

The Deloitte report also cites the example of a bikeshare system in China, which had the effect of nearly doubling accessibility to jobs, education and health care. This trial of making Micromobility available, increased the standard of living for the local community.

Because of the range of modern Micromobility devices available, it is estimated that more than 1.4 trillion miles of annual US passenger travel, and globally more than 4 trillion miles, could be converted to Micromobility. This has a market potentially worth hundreds of billions of dollars.

[Ref: https://humanpoweredsolutions.com/2019/12/23/micromobility-is-the-future/]

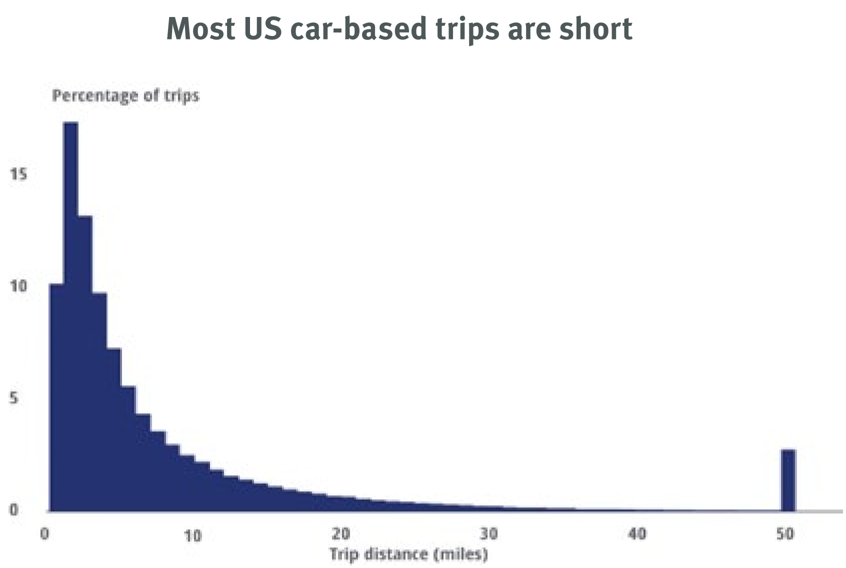

Figure 3-4: Deloitte analysis based on 2017 US National Household Transport Survey

Many new forms of Micromobility transport have different characteristics from conventional bicycles and push scooters. Therefore, these devices provide a new type of mobility not available to many urban dwellers in the past.

3.4 The current range of Micromobility devices

Low powered vehicles (LPV). These vehicles blur the lines between conventional scooters and bicycle classifications. In many countries, these forms of Micromobility are limited to less than 250 watts of continuous power. (Ref Rules & Regulations on Electric Cycles in EU - May 2017) They can include e-bikes, e-scooters, e-skateboards and other relatively naturally stable forms of Micromobility.

An explanation of a 'naturally stable devices' is: if the device is moving at more than 5 to 8 km/h, then several combined effects keep the device and rider upright:

- Front wheel gyroscope
- Trail effect or the front wheel being behind the steering axis
- The lower centre of gravity of the front of the device

(Ref: Prof. Andy Ruina, Vol III No.4, 2011, EZRA Magazine Cornell University)

Figure 3-5: Rental e-scooter

Where the LPV definition has issues is where:

1. the form of transport requires more power to move more weight of people or goods, e.g. cargo bike or
2. the motor of the vehicle is also used as an electrical stability mechanism

Electronically stabilised types of Micromobility have computers that manage the power to the motors and react to the weight distribution of the rider. To perform this task, the motors need to have their full power available at a moment's notice and usually 250 watts would not be enough to restore stability before the rider fell off.

Examples of these devices include the Ogo or Segway PT, which have one motor per wheel with each motor rated at approximately 750 watts.

Figure 3-6: Segway PT 2 x 750-watt motors, range 20 km, topspeed 20 km/h

Figure 3-7 Segway Ninebot mini pro 2, 2 x 800-watt motors, range 30 km, top speed 18 km/h (Source: Segway)

Figure 3-8: Ogo self-balancing wheelchair (Source: One News, TVNZ)

Other types of Micromobility also available at the time of writing, include the YikeBike, the Boxx, off-road e-skateboard, large-w heeled e-scooters and freight e-bikes. All of which have varying power outputs, top speeds and capabilities.

Figure 3-9: YikeBike model C: 200-watt motor, range 20 km, top speed 23 km/h (Source: YikeBike)

Figure 3-10: BOXX: 2 x 300-watt motors, range 80 km, topspeed 58 km/h and a heated seat (Source: BOXX Corp)

Figure 3-11: Stator 'self-balancing electric bike' 1000w motor, range 32 km, top speed of 40 km/h (Source: NantMobility)

Figure 3-12: Cargo bikes in use on the Wellington waterfront (Source: Stuff)

Figure 3-13: FiiK Street Surfer, range 30 km, top speed 37 km/h, regenerative antilock braking (Source: FiiK Skateboards)

Figure 3-14: Ninebot One Z10: 1800-watt, range 90 km, top speed 45 km/h (Source: Citi Wheel)

Mobility and powered wheelchairs should not be forgotten in this mix. They are usually classed as pedestrians, but can travel at 6 km/h, 12 km/h or up to 16 km/h in some cases. These types of device can have power outputs ranging from 230 watts up to 1500 watts.

Figure 3-15: Standard mobility scooter: up to 1500-watt, range 30 km, top speed 16 km/h

Figure 3-16: Newage B4: 1000-watt motor, range 40 km to 160 km, top speed 30 km/h (Source: Newage Vehicles)

Figure 3-17: Electric Wheelchair Tractor: 250-watt motor, range 30 km, top speed 7 km/h (Source: EJOYQ)

There are even more devices currently available and being invented all of the time. The Velomobile is a weather protected pedal and electric tricycle seen here used as a taxi.

Figure 3-18: Velomobile (Source: Regulations and safety for electric bicycles and low-powered vehicles July 2017- NZTA – Via Strada Ltd)

The Ubco 2 kW electric motorbike.

Figure 3-19: UBCO: 2000-watt, range 120 km, top speed 50 km/h (Source: UBCO Bikes NZ)

Figure 3-20: Outrider recumbent e-trike 4200-watt max, 750-watt continuous, range 320 km, top speed 56km/h. (Source: Outrider)

There are a vast number of variants coming into the Micromobility market. The author believes that if we are going to tackle the growing congestion issue, in our ever more populated urban centres, then we need to work out a way to harness the capabilities and dexterity of the many Micromobility devices available.

3.5 The rise of e-scooters

E-scooters emerged in 2017 as a new shared mobility service in the United States. Less than a year after their debut, e-scooters were operating in 65 U.S. cities. They did not arrive without disruption; companies like Bird and Lime began operations in 43 markets without government permits or consent. Several cities responded with cease and desist orders, fines, or both. [Ref 2018 E-Scooter Findings Report, Portland Bureau of Transportation]

Singapore also heralded the introduction of e-scooters as a way to manage the country's congestion issues. However, Singapore did not have infrastructure designed for the new technology. The clash between e-scooters and pedestrians became apparent very quickly with several fatalities in a short period of time. This led to the Singapore government revoking the 30 000 e-scooter licences that had been issued and refunding e-scooter users.

[Ref: https://www.bloomberg.com/news/articles/2019-11-04/singapore-to-ban-e-scooter- use-on-sidewalks-amid-injury-spike]

E-scooters rentals were also introduced to Australia and New Zealand during 2018 with varying responses. The shared mobility devices were adopted in some cities such as Christchurch and completely rejected in other cities such as Sydney.

[Ref: TfNSW https://roadsafety.transport.nsw.gov.au/stayingsafe/pedestrians/skateboardsfootscootersandrollerblades/index.html]

In Portland Ohio, the Portland Bureau of Transportation ran a pilot scheme to see if scooters could:

1. Reduce traffic congestion by shifting trips away from private motor vehicle use
2. Prevent fatalities and serious injuries on Portland streets
3. Expand access to opportunities for underserved Portlanders
4. Reduce air pollution, including climate pollution

The results of Portlanders' use were interesting. E-scooters replaced 19% of private car travel, 15% of ride hail and taxi trips. The results for tourists were even higher with 34% replacing the ride hail and taxi trips, and 14% replacing the use of a private car.

[Ref: 2018 E-Scooter Findings Report, Portland Bureau of Transportation.]

In New Zealand the results were similar with 28% of e-scooter trips replacing a trip by car, van, motorcycle, ride hail or taxi.

[Ref: Fitt, H. & Curl, A. (2019), E-scooter use in New Zealand: Insights around some frequently asked questions.]

What was also interesting in the New Zealand research was that 7% of the trips by rental e- scooter would not have occurred at all if that Micromobility option had not been available, i.e., having the option available increased mobility.

3.6 Where people want to ride e-scooters

A noticeable behaviour, recorded by these two Portland and New Zealand studies, was where e-scooter users rode the devices.

E-scooter users in New Zealand rode e-scooters in a number of locations. On the last ride, the respondents said they rode for all or part of the ride on:

- Main Road 45%
- Cycleways 65%
- Quiet residential streets 80%
- Shared-use paths 58%
- Footpaths 94%

At the time of the New Zealand survey, e-scooters were only allowed to be ridden on the footpath and road, but not on cycleways. This NZ law is currently under review.

[Ref: https://www.nzta.govt.nz/vehicles/vehicle-types/low-powered-vehicles]

As part of data collection and dissemination for this ADA thesis paper, a response was produced by Aurecon to help guide this NZ Accessible Streets law change. (See Appendix 1)

In Portland, Ohio, as part of the survey of e-scooter users, a question was asked about where people felt comfortable using e-scooters:

- When there was a protected bike lane, only 8% rode on the sidewalk (or footpath)
- When there was a bike lane marked on the road 21% used the sidewalk
- When on a street with no bike lane 39% used the sidewalk
- When the speed limit was 20 mph (32 km/h) 18% used the sidewalk
- When the speed limit was 30 mph (48 km/h) 50% used the sidewalk
- When the speed limit is 35 mph (56 km/h) 66% used the sidewalk

It should be noted that at the time of the survey, in Portland, e-scooters were illegal on the sidewalk.

Both in Portland and New Zealand, as in many other regions, a number of people questioned the use of e-scooters on the footpaths and sidewalks.

During the NZ survey:

- 51% of users of e-scooters thought the footpath was the appropriate environment to ride their devices
- 26% of non-users thought the footpath was the appropriate environment to ride e- scooters.

At the time of the NZ survey, the speed limit for rental e-scooters was 25 km/h and they were illegal on cycleways.

During the Portland survey:

- 27% reported e-scooters on sidewalks reduced comfort by making pedestrians feel unsafe
- Sidewalk riding was a key concern voiced by the Pedestrian Advisory Committee, TriMets's Committee on Accessible Transportation (CAT), and the Portland Commission on Disabilities (PCOD)
- PBOT Concluded: “For us, this clearly demonstrates how important it is to have protected facilities that minimize conflicts between pedestrians, e-scooters and cars.”

Note: At the time of the Portland survey, the speed limit for rental e-scooters was 15m/h (24km/h) and they were illegal on sidewalks.

These examples show that there is a problem with where and how e-scooters are being used. The current transport infrastructure has not been designed to cater for this new mode of mobility.

3.7 Trends in crash rate

In New Zealand, the Accident Compensation Corporation (ACC) is a government entity which:

- Covers all medical and compensation costs
- Operates on a no blame basis
- Covers all people in NZ for all accidents

An ACC study noted the number of accidents involving e-scooters was reducing from 2018 to 2019, even though the number of users was increasing.

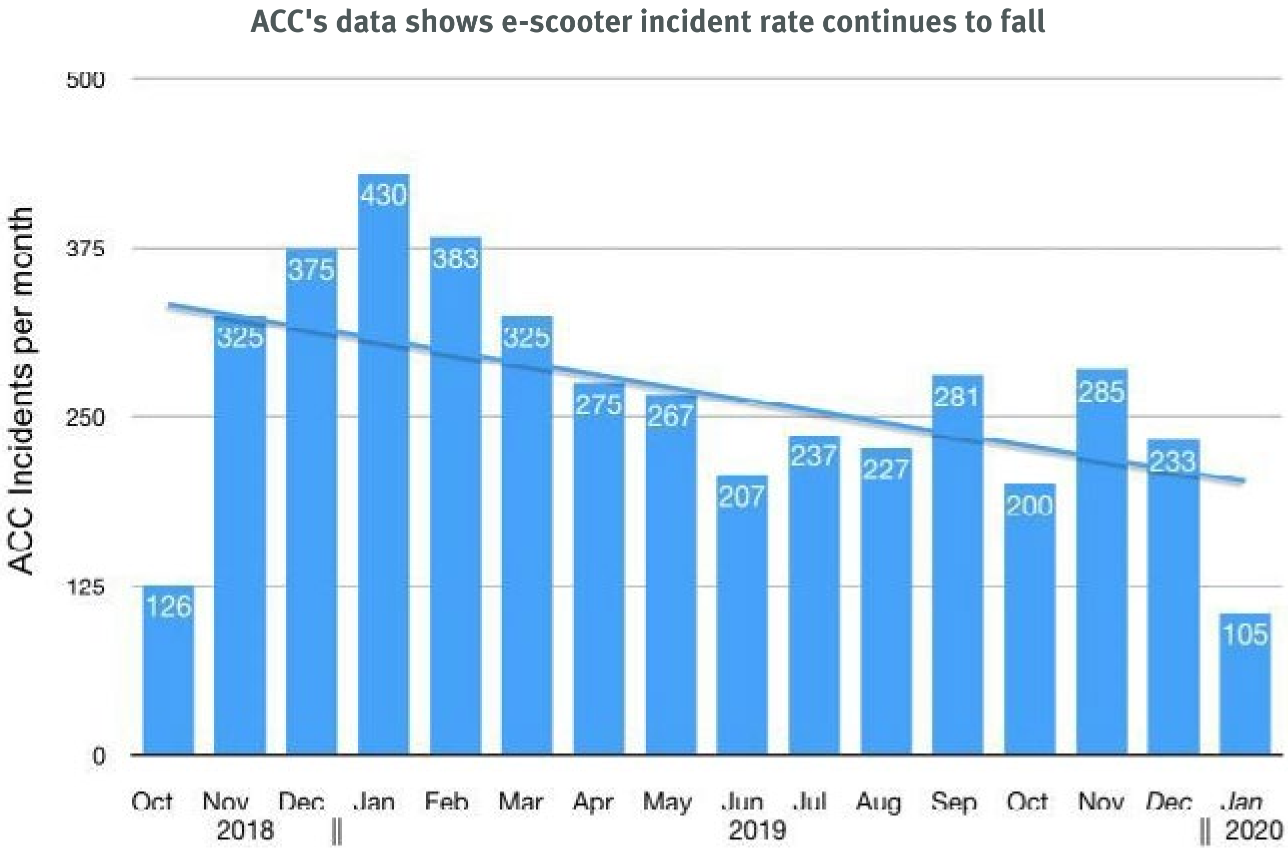

Figure 3-21: New Zealand, ACC accident trend rate for e-scooter users 2018/2019

[Ref: https://segwaynz.wordpress.com/2020/01/31/acc-reports-injuries-continue-on- downward-trend-as-auckland-council-study-declares-e-scooter-benefits-outweigh- injuries-from-use]

This trend was corroborated by the International Transport Forum's report into Safe Mobility. The study recorded a similar reduction in reported accidents even though the numbers of Micromobility users was increasing.

Number of crashes reported by riders of two standing e-scooter companies

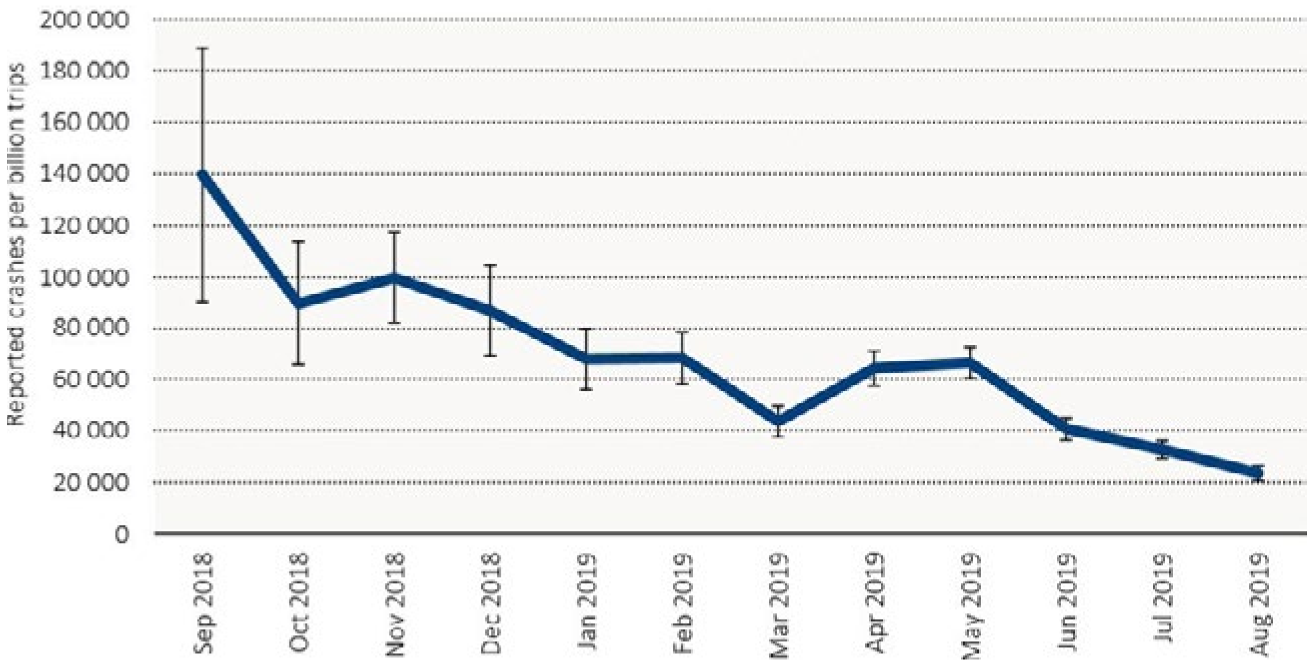

Figure 3-22: Number of crashes recorded by two e-scooter rental companies in the USA

[Ref: https://www.itf-oecd.org/sites/default/files/docs/safe-micromobility_1.pdf]

The conclusions of these reports were:

1. The skill levels of users were increasing.
2. Owner riders who were more likely to commute, were less likely to take risks than riders of rental scooters.

The Auckland City Council concluded from the NZ ACC statistics: "...the social benefits of mobility of e-scooters outweigh the social cost of injury."

[Ref: https://www.stuff.co.nz/business/118429558/escooters-benefits-outweigh-injuries- from-use-auckland-council-report-says]

The Auckland City Council report also pointed out that all modes of transport entail risk and give rise to injuries (including walking), and the evidence they collected showed that e- scooters are a less injurious and costly form of transport compared with journeys taken in cars and on bicycles.

3.8 The mode of vehicle discussion

Currently in most countries, allocation of road space and legal classification of vehicle is based on **what** is allowed in that road space i.e. the **mode** of the vehicle. Vehicle modes and legal classifications include:

- Pedestrian
- Cycle
- Motorcycle
- Car
- Taxi
- Commercial vehicle
- Bus
- Tram

3.8.1 Mode based classifications

The designs of small Micromobility devices keep changing. Authorities spend time and effort classifying what each new device is by putting it into one of the accepted modes, then applying the rules that govern that mode.

This leads to some devices being forced into areas of the road cross section which do not suit the way they are operated, e.g. in New Zealand:

- Push-scooters
- E-scooters
- Small bicycles
- Skateboards
- E-skateboards
- Wheelchairs
- Mobility devices

are all allowed on footpaths and roads, but the e-scooters and e-skateboards are not allowed on the cycleways.

This contrasts with bicycles and e-bicycles being classed as bicycles, and therefore only being allowed on cycleways and roads in New Zealand.

[Ref: section 2.3, Land Transport Road User Rule 2004. www.legislation.govt.nz]

3.8.2 Mode merge

A dilemma that needs to be dealt with is one of 'Mode merge'. Pedestrians can now use mobility devices such as electric scooters to:

- Enhance their travel experiences
- Help in the last mile and first mile commute from home to work when using public transit
- Make their travel faster with less effort
- Carry bigger loads over longer distances

At the point of using a mobility device, the pedestrian has merged between an on-foot mode to an on-wheel mode.

Mode merge has also affected cyclists. The invention of small powerful electric motors and long-life rechargeable batteries has resulted in many more people taking to the cycle lanes and streets on fast moving devices. These mobility devices can carry bigger loads further without the need for strenuous activity, and without being at the mercy of public transit routes or timetables.

The issues occur at the boundaries of these modes. An e-bike does not have the characteristics of a bicycle, nor does it have the ability of a motorbike. The same can be said for modern electric scooters. They appear similar to push scooters, but that is where the similarities end. Modern e-scooters have the ability to be propelled at much higher speeds than push scooters. E-scooters have powerful braking systems, large tyres, forgiving suspension and even, in some cases, technologies such as GPS speed limiting, ABS brakes and electronic stability control.

However, the questions that are asked of these assisted transport modes include:

- Are they similar enough to be called a bicycle?
- Should they be considered and regulated as bicycles?
- Where do Yike Bikes, Segways, and Hoverboards fit in a new vehicle classification?
- Where do autonomous delivery drones fit?

In the binary design of "footpath for pedestrians and road for motor vehicles", the author believes these devices do not fit as a pedestrian or as a motor vehicle.

In fact, should we even be trying to classify these new modes under "pedestrian" or "motor vehicle" at all?

Mode classification can force devices and their users into places that are not appropriate. The history of the New Zealand law is: e-scooters were not widely available when the laws around bicycle lanes were written. Therefore, e-scooters have been mode classified to only be used on footpaths and roads. This is because e-scooters have not been classed as bicycles under NZ law, and therefore are not deemed to be appropriate for cycleways. Also, not being classed as bicycles means the wearing of a helmet is not compulsory. This is opposed to a bicycle in NZ, where wearing a helmet is compulsory.

Forcing e-scooters onto roads with speed limits that are more than twice the speed capability of the e-scooter, puts the e-scooter users at considerable risk. This large speed differential provides a risk of conflict at most overtaking occasions. This conflict risk was noted in the Portland e-scooter survey.

The eye height of an e-scooter rider and that of a cyclist are similar, the speeds when unregulated are similar and, in some cases, both devices can be hired using the same app on a smartphone.

Commentary in media has been that the NZ laws for the use of these Micromobility devices are not appropriate.

[Ref: https://stormrides.nz/blogs/electric-scooter/electric-scooter-laws-in-nz-the-ins- the-outs-and-the-idiocy]

The NZ government has noticed this dichotomy in NZ laws in 2020. As mentioned in section 3.7, Waka Kotahi the NZ Transport Agency asked for feedback on new laws that would allow e-scooters on bicycle lanes and slow-moving cycles on footpaths. (See Appendix 1 for the Aurecon NZ Ltd response to the consultation.)

Even with these proposed law changes, the author still believes classifying Micromobility based on mode, is not a way to move forward. New Micromobility inventions will continue to appear and therefore will be classified under inappropriate mode types.

Personal risk and capability vary considerably across each mode i.e., e-bikes can now go as fast as cars. This means that categorising vehicles by their mode is no longer a safe and efficient way of organising vehicles and devices in the transport network.
The author believes we need to move away from allocation of road space based on classifications of transport mode; then base the allocation of road space on the functionality and travel characteristics of the vehicle itself.

3.8.3 Criteria for allocation of road space

Allocation of road space should be:

- As safe as practicable
- Easily understood
- Predictable
- Not specifically based on vehicle type
- Based on some other criteria that all transport has: e.g. speed, breaking ability, size or width etc

The author proposes that we redesign the roads based on people's future transportation needs and reorient and redesign cities to allow for further Micromobility. The current system is not working and not future-proofed.

The author's theory is that the **mode** being used is not what matters. It is **how** transport is being used and where.

If we take, for example, a small motorbike versus a V8 sedan:

- Both are required to have certain safety features
- Both are allowed to operate in the same road space
- Both require lights, a horn, brakes, tread on tyres etc.
- Both require an operating licence and regular safety checks
- The operators (drivers/riders) of the two vehicles must obey the current road rules e.g. keep left unless overtaking, obey give way rules and traffic signs, keep to the designated speed limit for the specific area where they are operating etc

These two vehicles have quite different load, power and comfort levels. However, they must still follow the same speed limits, road rules, give-way laws and have certain safety features.

Some jurisdictions have classified some transport devices as '**pedestrians**' such as:

- Powered wheelchair
- Wheeled recreational device
- Low-powered mobility device
- Mobility device
- Pedestrian with a shopping trolley
- Child on a small-wheeled bicycle

However, bicycle including electric bicycle is another mode all together.

[Ref: Table 1A, Accessible Streets - Overview to the rules, Waka Kotahi, March 2020]

The author believes classifying Micromobility vehicles into a number of classes of mode is a futile exercise. This is because the invention of new Micromobility transport devices is increasing the number and complexity at the boundary of these classifications. Many Micromobility devices do not sit easily in the class of pedestrian, bicycle or motor vehicle.

A number of jurisdictions are trying to create new classes of vehicle such as in New Zealand, where the class of 'motorised device' is being considered. However, they are grappling with the issue of regulation around limits of power output and where each classification of device (or mode) should be allowed to operate.

As stated earlier, some devices use power to stabilise the operational use: e.g. a Segway or Hoverboard. A limit on the power of the motor rules out the use of these modes, in many shared-use areas. Even though these devices can and do get used safely in many shared-use areas.

Coming back to the premise that the mode or classification of the device should not matter, it is how the device is used and where it is used, that should be considered. This is analogous to the small motorbike versus V8 sedan: both the motorbike and the sedan must follow the same laws and be operated in a similar way.

The small motorbike can travel more economically around town, while the sedan can carry a larger load, more accessories and provide more comfort for the passengers. But still, the same road rules apply equally to both vehicles.

3.8.4 Proposal for classification of MMD

The author proposes that all bicycles, scooters, e-scooters, e-bikes, Segways, delivery drones, YikeBikes etc. should be one class of 'Micromobility device' (MMD). The MMD standard would have size limits of width, height and length, so that physical fit criteria can be set for geometric designers and planners.

All MMD's should be required to have standard safety equipment fitted, e.g. if they are to be operated at night then lights at front and back.

That is where the design limits should end. All other requirements for the MMDs should be based on the operation of the device and be specific to where they are being used, e.g. if they are to be used on the footpath, then a speed limit would apply that is appropriate to the geography and other users, say 10 km/h.

If the MMD device is being used on the road, then the road speed limit should apply. Additionally, if the MMD is to be used on the road, stringent safety features would be required e.g. the wearing of a helmet for the operator, a braking system etc.

But again, many MMD vehicles do not fit this binary arrangement of footpath or road. The issues occur at the boundaries. If a device is not practical to operate at 10km/h on the footpath and is not fast enough to operate on the road with cars and trucks, where should they be used?

Redesign the road

4 Redesign the road

The author proposes that we redesign the roads to cater for these new MMDs and not be locked into classification by mode. We should instead, be driven by design rules based on etiquette and practicality, which provide access for all.

A design continuum for road layout is proposed. This would be where slow, people and devices, stay to the left, faster pedestrians and devices pass on the right (of course reversed for left hand drive countries). Speed should be the deciding factor for where the device or person should be on the carriageway, not the mode of travel.

We should then redesign our roads to cater for this new method of operation. All road designs would need to be based on the available width and the desired use for that specific section of road.

What the author wishes to consider is: Can we classify and allocate road space based on speed?

The author is proposing that movement on our transport links should be organised by function rather than form.

4.1 Examples in other areas of science

Side friction occurs in a pipe or river due to particles being stationary along the edge. These stationary and slow-moving particles interact with the neighbouring particles and slow the flow near the sides. As the distance from the sides increase, the speed of the particles increases until the maximum speed in the fluid occurs in the middle or centre line. This is similar to traffic on a motorway, especially past roadworks on the road shoulder. Slower speeds occur in the lanes near the stationary road works and faster speeds occur nearer the centre line of the carriageway.

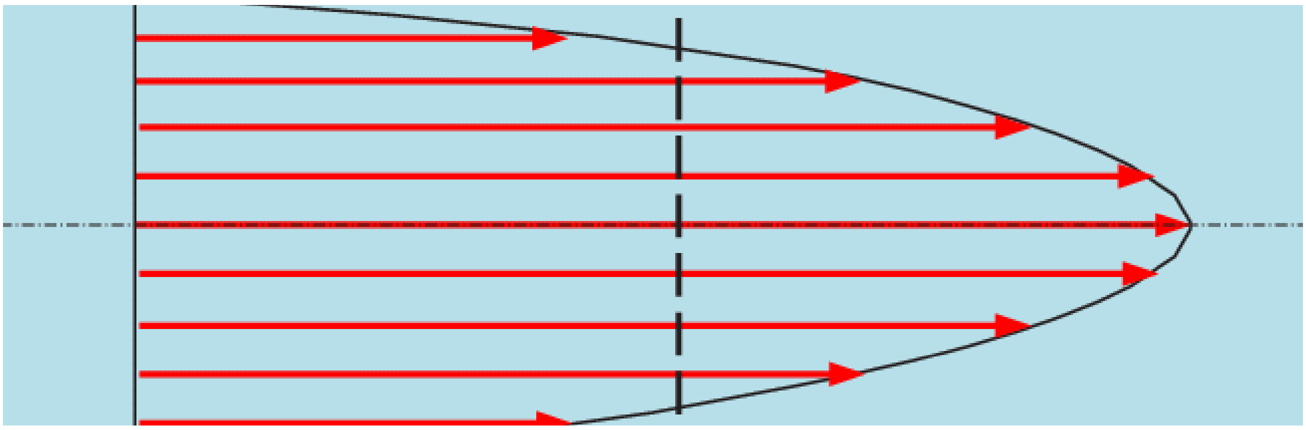

Figure 4-23: Representative speed flow curve for a pipe or river in laminar state

However, if eddies form in a pipe or river, the flow is interrupted as slower and faster particles intermix reducing the efficiency and predictability of the particle movement. These different speeds or sizes of particles in a pipe create turbulent flows, which wastes a lot of energy with particles jostling to get past each other in a far more random state.

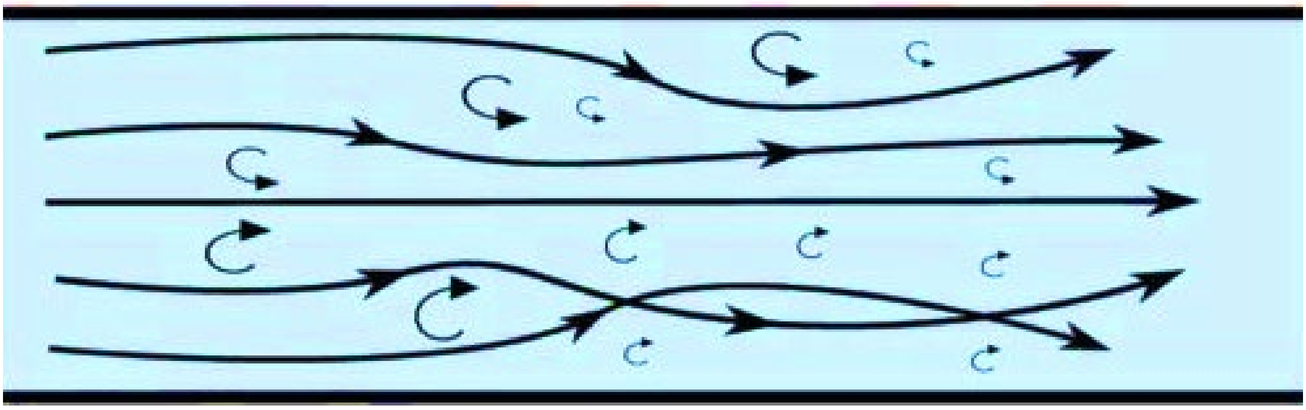

Figure 4-24: Representative speed flow curve for a pipe or river in turbulent state

When we compare this to current mode-based separation on our streets, the flows are more like the turbulent flows in a river because:

- Slow walkers and faster runners interact
- Slow pleasure cyclists and faster commuter cyclists interact
- E-scooters and e-bikes weave among slower forms of mobility

For our roads, if we have passing on the right only on a continuum, then we get flows that are far more like the laminar liquid example and less like the turbulent fluid examples.

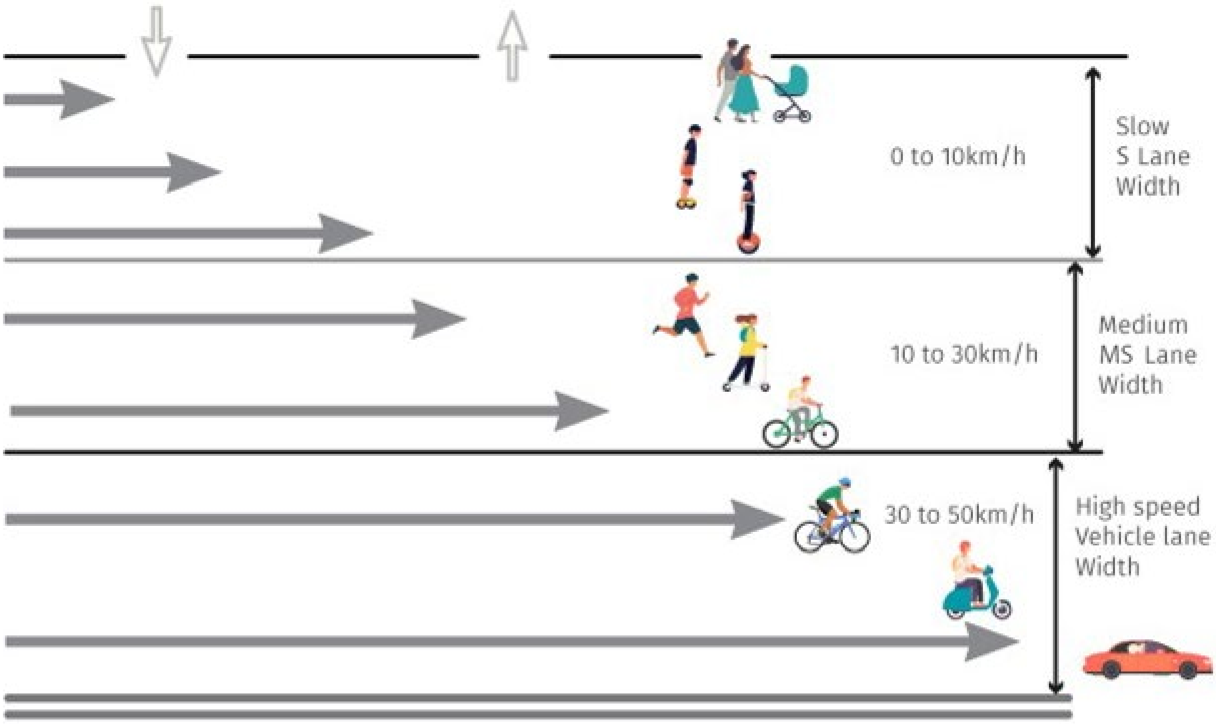

Figure 4-25: Proposed sketch of speed profile over redesigned road cross section

The author proposes that the way people are moving, not what is moving them, is a better way to design our road cross sections.

If we want people to use the Medium speed lane (MS Lane) or 'S' lanes (footpath), then we should be designing the lanes for the number and movement characteristics expected of the users.

Users of MS or S lanes need to feel comfortable and able to move at the speed they desire. Transport engineers call this comfort level a Level of Service or LOS. LOS explains how the user of the service, be they pedestrian, car driver or cyclist feels as they undertake their journey. LOS A and B are quite comfortable for users. At those LOS users are able to move freely and at their own pace with little interaction with others.

[https://www.researchgate.net/figure/The-level-of-service-criteria-Fruin-1971-defined- a-range-of-values-to-standardly_fig5_266384664]

To achieve a 'desire to use' and 'feeling of safety' when traveling on a footpath or MS, we should only be designing for LOS A in most cases, and LOS B for more densely trafficked areas. LOS C and D should only be used in pedestrian and MS for forced flows such as fire egress. This is because the volumes required, and the feelings of the individual users are of less importance during a fire event.

Therefore, we should use Design Led Thinking to develop the right sized lanes for our proposed volumes and speeds, i.e., sizing the lanes to the number of expected users.

4.2 Widths for S lanes

Where there is predicted to be low numbers of slow-moving people and mobility devices, then a narrow S lane (footpath) of say 2 m may be sufficient, provided people are all traveling in the same direction and overtaking only occurs on the right. However, if volumes are higher or two-way travel is desired, then 3 m to 5 m S lanes should be considered.

The desired width for a footpath is listed in table 4-1.

[Ref: Transport Research Board. Highway Capacity Manual. Washington DC: Special report 209,1985. Chapter 13]

If we assume all users of slow-moving devices move in a similar way to pedestrians, then the S Lane width to volume ratios will be similar to current design criteria. (Note: the author believes further research should be undertaken in this area to critique this assumption.)

S lane width m	LOS A vol ped/hr	LOS B vol ped/hr	LOS C vol ped/hr	LOS D vol ped/hr
1	195	390	780	1230
1.5	390	780	1560	2460
2	585	1170	2340	3690
2.5	780	1560	3120	4920
3	975	1950	3900	6150
3.5	1170	2340	4680	7380
4	1365	2730	5460	8610
4.5	1560	3120	6240	9840
5	1755	3510	7020	11070

Table 4-1: S lane width to volume. (Adapted from Transport Research Board. Highway Capacity Manual. Washington DC: Special report 209,1985. Chapter 13)

Figure 4-26: Wide footpath or S-lane. [Picture source Daily Telegraph]

The rules that should be applied for using slow speed S lanes.

It is proposed that S lanes, like all other road lanes, should have rules of etiquette and use. These could include:

- Keeping left is encouraged, i.e. this was used as a social distancing policy during the 2020 Covid-19 pandemic. (See fig 4-27)
- A speed of zero to not more than 10 km/h.
- [Ref: p77 Accessible Streets - Overview to the Rules, Waka Kotahi, March 2020]
- Overtake only on the right (this is to enhance predictability)
- Behind gives way to Infront (this would be the same as for boats on the water) [Ref: https://www.maritimenz.govt.nz/recreational/rules/default.asp]

Figure 4-27: Keep left footpath message for Wellington New Zealand (May-June 2020)

The speed profile for the S lane would be similar to that shown in fig 4-28.

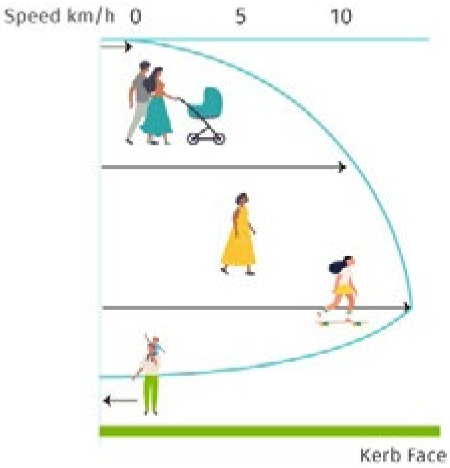

Figure 4-28: Sketch of proposed speed profile of S lane (footpath)

4.3 Widths for Micromobility lanes

A similar argument should be put forward for the widths of the Medium Speed lane (MS Lane) as for the widths of the S lane. If we wish people to use the MS lane, then the LOS should be A or at least B. Any lower than LOS B, then the users will start to feel unsafe and will not opt to use the facilities.

An absolute minimum width for a single direction MS lane should be 2.0 m. This would feel very tight when passing and would require good control by both parties. A width of 3 m would be far more comfortable, allowing good distancing when overtaking. Any widths over 3.0 m would require good 'keep left' discipline, so that lower speed users did not impede higher speed users.

Table 4-2 proposes widths for the MS, based on predicted volumes of users irrespective of device.

MS Lane width m	LOS A vol MMV/hr	LOS B vol MMV/hr	LOS C vol MMV/hr	LOS D vol MMV/hr
1	0	0	0	1171
1.5	0	0	1968	2342
2	0	1921.5	2952	3514
2.5	1728	2562	3936	4685
3	2160	3202.5	4920	5856
3.5	2592	3843	5904	7027
4	3024	4483.5	6888	8198
4.5	3456	5124	7872	9370
5	3888	5764.5	8856	10541

Table 4-2: Adapted from [Table 8-4, Flow Characteristics on bike paths and bike lanes, 13 Edition, Fundamentals of Traffic Engineering, University of California at Berkeley]

4.3.1 Proposed rules for the use of Medium Speed Lanes (MS):

- Speed from 10 km/h to 30 km/h
- Vehicle/person in front has right of way
- Only overtake on the right

All people and devices, no matter what their propulsion, should move out of the MS lane if their speed is not within the upper and lower speed limits proposed for the MS lane, e.g. 10 km/h to 30 km/h.

Note: These are the types of rules which can be programmed into autonomous delivery drones. However, further research is required into this aspect.

Figure 4-29: Starship Technologies testing a delivery drone. (Source: Financial Times)

The speed profile for a Medium Speed Lanes (MS) is likely to look similar to that proposed in fig 4-31:

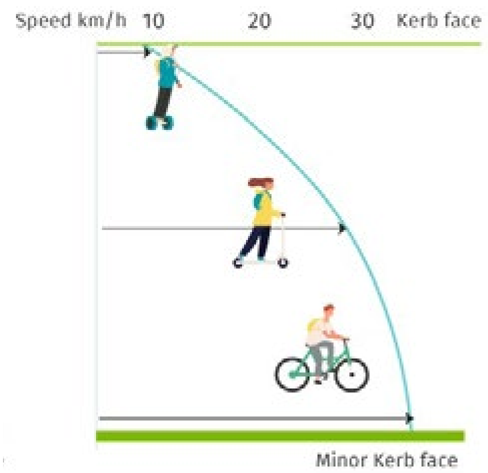

Figure 4-30: Sketch of proposed speed profile of Medium Speed Lane(MS)

4.4 Safety of traffic in one directional laminar flow

In most jurisdictions, vehicles that cannot sustain a constant set speed, cannot use a motorway. Separation by direction is important. The safest roads are the ones where there is:

- Separation of bidirectional conflict
- Overtaking only on the right
- Speed differentials are managed by limiting the slower vehicles to the left lanes
- Vehicles that want to travel fast, move into the right lanes

The Autobahn in Germany is a good example of this: rules of etiquette are in play and there is no speed limit.

Because of the separation of conflicts and there is predictability of what other vehicles are going to do, the Autobahn is far safer per vehicle kilometre travelled than other roads (see table 4-3). This is despite the speeds being much higher than for other road classes.

Road Class	Injury Crashes	Fatalities	Injury Rate[rate 1]	Fatality Rate[rate 1]
Autobahn	18,452	428	82	1.9
Rural	73,003	1,934	249	6.6
Urban	199,650	977	958	4.7
Total, Average	291,105	3,399	401	4.6

1. ^ a b per 1,000,000,000 travel-kilometres

Table 4-3: Comparison of crash rates per kilometre per road type in Germany

[Ref: "Traffic and Accident Data: Summary Statistics – Germany". Bundesanstalt für Straßenwesen (Federal Highway Research Institute). October 2014]

As on the Autobahn, if the conflicts of direction, speed differential and unpredictability are removed, then safer journeys are the result. The author surmises therefore, the more predictable and laminar the flow, the less conflicts and accidents are likely to occur. Separating vehicles and devices into speed groups and applying user rules is one way of achieving this goal.

As discussed previously, users and vehicles that are wishing to travel at a speed in excess of 30 km/h should move out of the MS lane, and operate in the high-speed(HS) vehicle lane.

4.5 Proposed rules for the high-speed vehicle lane

- Speed from 30 km/h and up
- Vehicle/person in front has right of way
- Only overtake on the right

The speed profile of the high-speed lane would look similar to that in fig 4-31:

If the vehicle or device, irrespective of mode, is not capable of sustaining a constant set speed of 30 km/h or more, then they should not be in the high-speed vehicle lane.

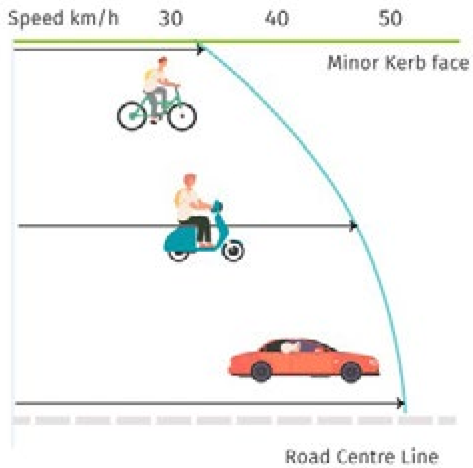

Figure 4-31: Sketch of proposed speed profile of high-speed(HS) lane

What would the new road cross section look like?

5 What would the new road cross section look like?

To illustrate the proposed difference for urban areas, we can compare two examples of road cross sections:

1. Binary modes of pedestrians on footpath and cars on the road as illustrated in fig 5-32.

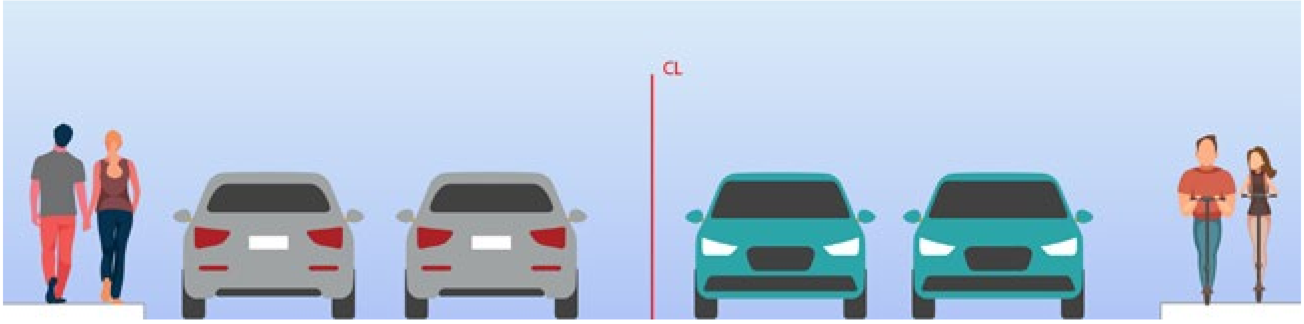

Figure 5-32: Sketch of binary road cross section

2. Proposed new urban cross sections based on speed and how the users are interacting with the road space as seen in fig 5-33.

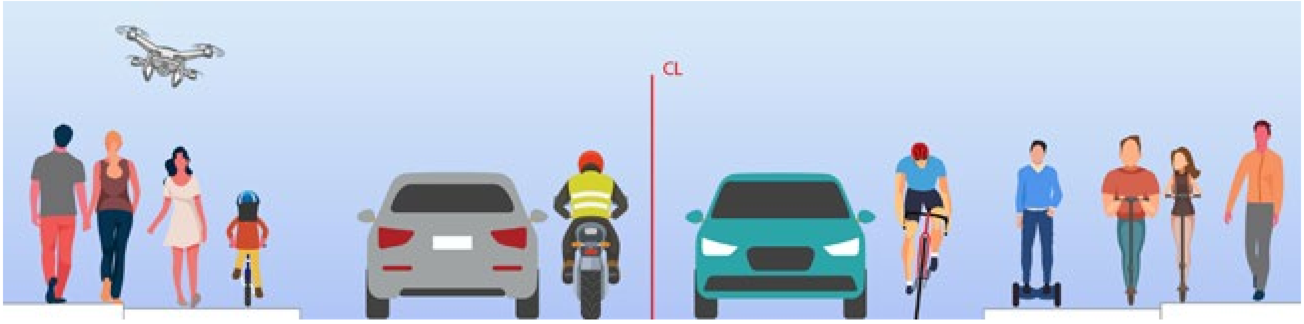

Figure 5-33: Sketch of user operationally defined function and speed cross section

5.1 Two-way speed flow curves

If we assume a two-way flow can occur on a street, the flow across the entire cross section would look similar to the profile in fig 5-34.

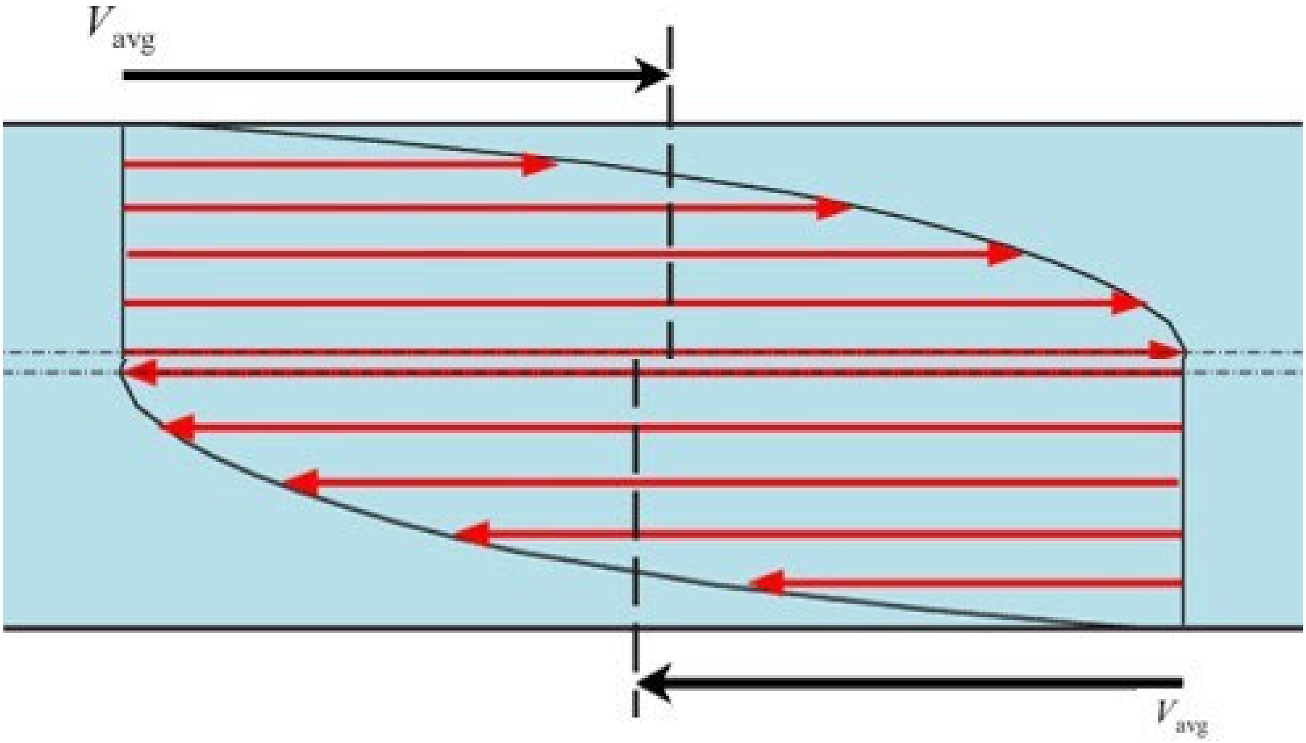

Figure 5-34: Sketch of speed profile over the S lane, MS lane and HS lanes in two directions

5.2 Worked examples for S and MS Widths

Using the width tables 4-1 and 4-2 developed earlier, we can create table 5-4. The desired S and MS lane widths can be designed, based on user volumes and congestion preferences. Example width to volume ratios for LOS A and LOS B are shown below in table 5-4.

S Lane	LOS A	LOS B	Micro Mobility	LOS A	LOS B
S lane Width m	vol	vol	MS lane Width	vol	vol
metres	ped/hr	ped/hr	metres	MMV/hr	MMV/hr
1	195	390	1	0	0
1.5	390	780	1.5	0	0
2	585	1170	2	0	1922
2.5	780	1560	2.5	1728	2562
3	975	1950	3	2160	3203
3.5	1170	2340	3.5	2592	3843
4	1365	2730	4	3024	4484
4.5	1560	3120	4.5	3456	5124
5	1755	3510	5	3888	5765

Table 5-4: Desired S lane and MS lane widths matched to user volumes & LOS

As can be seen in Table 5-4 the volumes achievable in a 3.5 m wide MS lane are well in excess of 1500 veh/h, which is the volume of vehicles a standard 3.5 m urban road lane can handle in one hour.

This increase in volume per hour is because of the smaller footprint of the Micromobility devices and the ability to pass each other within the width of the MS lane.

Fig 5-35: A large volume of cyclists occupying a similar footprint to three cars and a small truck (Source: Arc Publishing)

5.2.1 Illustrations of S lane and MS lane widths

Two different LOS example cross sections are sketched below.

1. For Level of Service A (ideal for safety and encouraging use), the lane widths could be sized similar to that in fig 5-36.

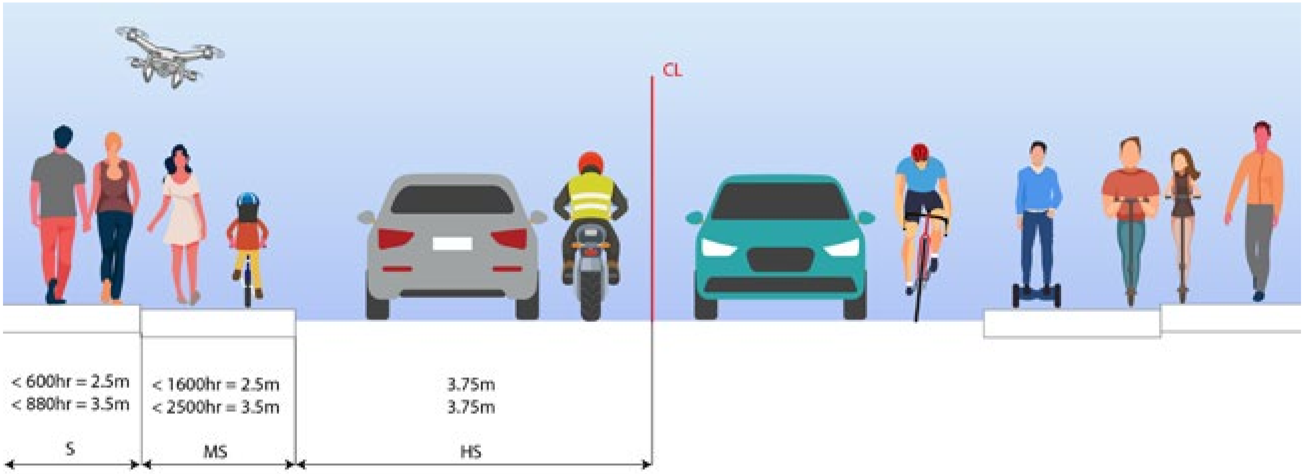

Figure 5-36: Desired lane widths for S lanes and MSs for Level of Service A

2. For Level of Service B, (Practical to handle additional flows in constrained areas) the lane widths could be sized similar to that of fig 5-37.

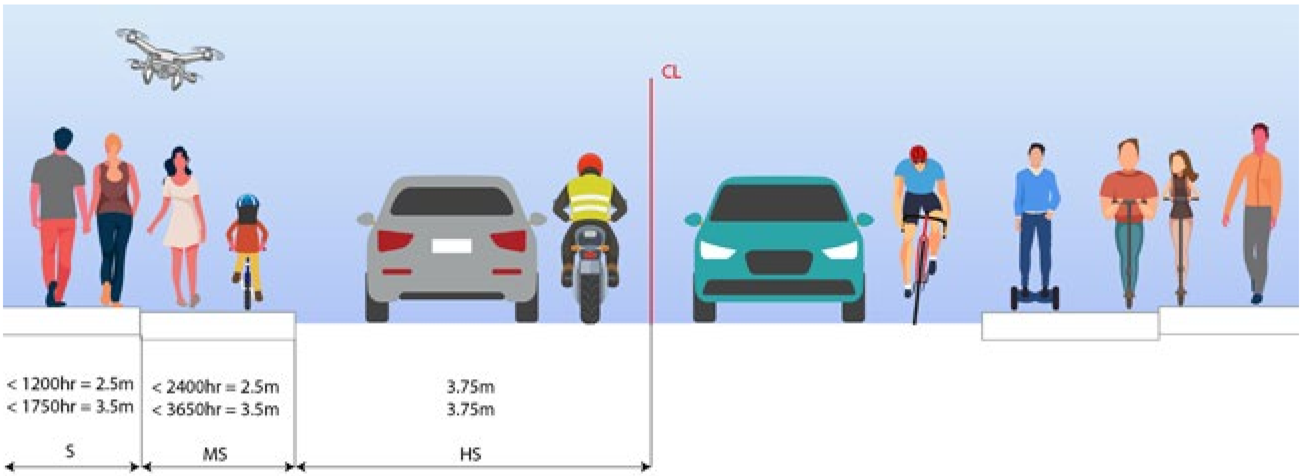

Figure 5-37: Practical lane widths for S lanes and MS lanes for Level of Service B

S lanes and MSs could be installed along many roads. The physical look and feel could be similar to the picture in fig 5-38.

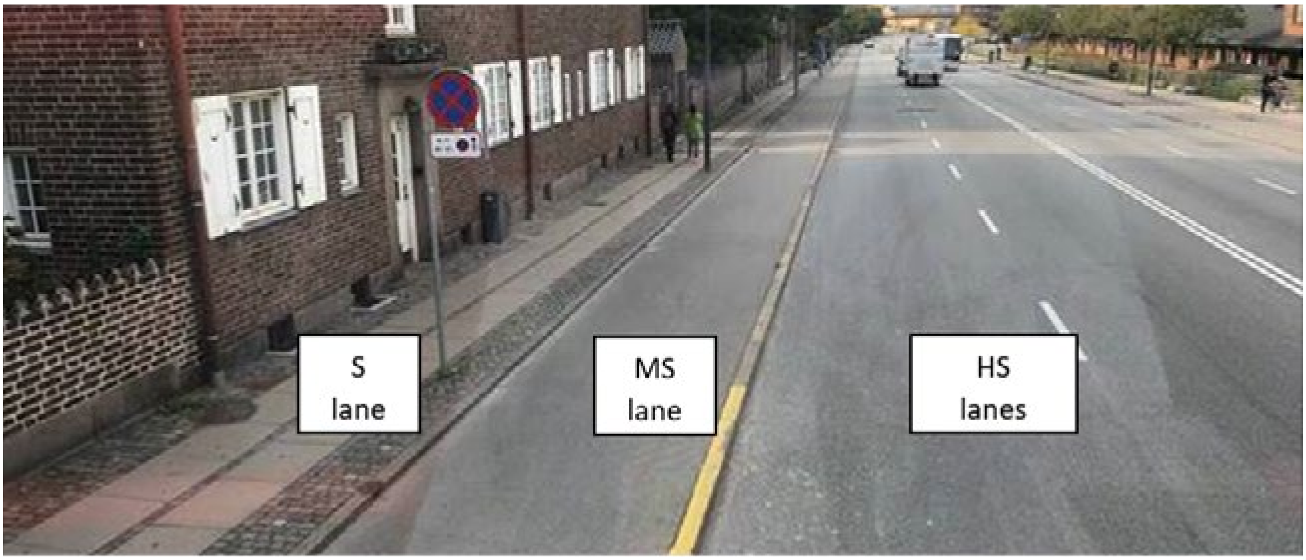

Figure 5-38: Illustration of Slow, Medium-Speed and High-Speed lanes

The separation of the S lane from the MS lane and the HS lane do not need to be permanent solid barriers. Investigation into the use of moveable barriers or profiled pavement markings should be considered in pilot trials. This would allow widths to be changed depending on user needs and measured volumes, along with potentially even changing widths of the lanes by time of day. Future research is required in this area.

Intersection controls

6 Intersection controls

6.1 Traffic signals for MS Lanes

Adding new lanes to the current binary road layout needs to be considered very carefully, especially when we look at the conflict points of intersections. There are a range of options that need to be considered and further research is warranted. Traffic signals to control the users in the vehicle lanes and pedestrian crossings already exist. Adding additional controls for the MS lane is one solution.

Additional signal heads have been used in Europe for many years and are currently being trialled in Auckland. They work in a similar way to other traffic signals and appear to be easily understood. Data on the effectiveness of the signals is yet to be released.

Figure 6-39a: Vehicles held from turning left so that MS Lane (cyclists here) can proceed

Figure 6-39b: Vehicles held from turning left and MS Lane users warned of signal change

Figure 6-39c: Vehicles allowed to proceed left while MS lane users are held on red signal

6.2 Conflict Zones

Another issue when dealing with intersection is to keep vulnerable road users out of the conflict zones. One of the worst places to be is in the middle of an intersection waiting to make a turn. This is often a conflict point between two vehicles.

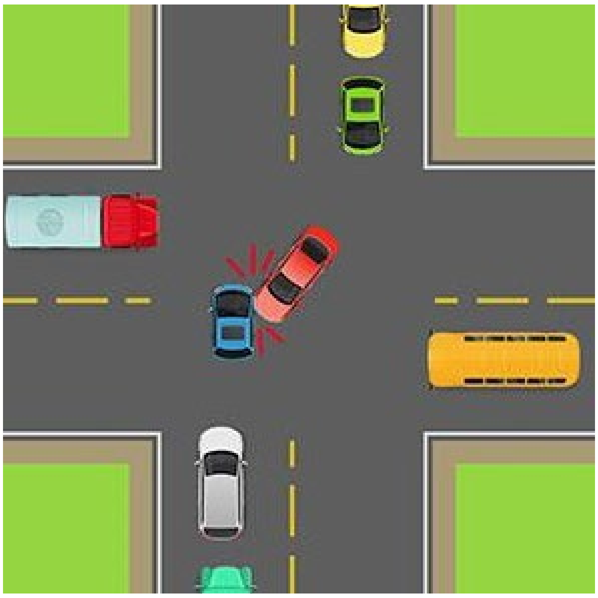

Figure 6-40: Illustration of conflict zone in the centre of an intersection

One way of avoiding this type of crash for MS lane users, is to not allow vulnerable Micromobility (MM) users into the centre of the intersection. Instead, create 'box turn' areas. Box turns are called 'hook turns' in Melbourne and are used to keep traffic from conflicting with trams. Box turns put vulnerable road users in front of traffic which is about to travel through an intersection as shown in fig 6-41.

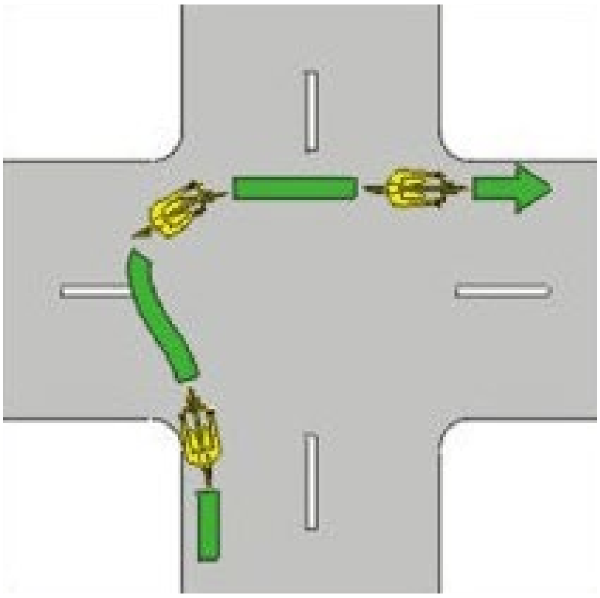

Figure 6-41: Illustration of box turn movement at a cross intersection

Potential road marking that could be used to create box turns for MS lane users may look similar to fig 6-42. The road marking directs the MM lane users to a safe location in front of the stationary through movement traffic from the adjacent side road. This marking keeps the MS lane users away from the conflict zone in the centre of the intersection.

Figure 6-42: Possible road marking to create 'box turns' for MS lane users at an intersection

Stakeholders

7 Stakeholders

Redesigning the road network involves many stakeholders. The stakeholders who have the most to win and the most to lose are the governments, councils and road controlling authorities. If the redesign is done well, the cities will thrive with more life and vitality as in the case of Copenhagen. On the other hand, if the redesign is done poorly, then the life blood of businesses, being able to move people and goods around easily and quickly, could be at risk. Good design, consultation and holistic planning is required to make any major transport change work.

More research and piloting work are required in these areas. However, if we look at what would be good measures for success, we could propose:

Goal – Movement quality for vulnerable users

Objective – Less conflicting interactions

Indicator – Flow performance

Controls – Physical and logical control by speed, space, etiquette and direction

As with the advent of Mobility-as-a-Service (MaaS), the lever for change can be the users themselves. Once people had discovered the benefits of using companies like Uber and Lyft then attempts to protect industries such as taxi services can become a political nightmare. [https://fortune.com/2019/11/27/uber-london-ban-global-ride-hailing-backlash/] The lever for change is likely to be the demand for equity for Micromobility users. This would be in demands for lane-width space that is safe, efficient, and does not increase the risk for vulnerable transport users or pedestrians.

Potential Impacts

8 Potential Impacts

Some potential impacts of redesigning the road cross section include:

- People may move out of cars into Micromobility use:
  - Induced demand is a well-known phenomenon to transport professionals. It is a theory born out of experience. If more road space is provided for cars, more people will drive. [Ref: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762976/latest-evidence-on-induced-travel- demand-an-evidence-review.pdf]
  - The counter argument to this is the same: If additional road space is not provided for cars, then more car trips will not occur. The potential demand is still there but has not been realised or induced.
  - If we apply the same logic to S lanes and MS lane, and provide more capacity for these types of users, more of the potential demand will be released as induced demand for pedestrians, cyclists and Micromobility users. [Ref: https://www.sciencedirect.com/science/article/pii/S0966692316304008]
- Another major benefit of redesigning the road space is that the types of transport, in the S lane and MS lane, have a much smaller spatial footprint. Therefore, more users can take advantage of the benefits of mobility. This is especially pertinent to lower socio-economic communities who get a better standard of living when mobility becomes more available to them. See fig 5-34a. [Ref: https://www.census.gov/library/publications/2014/acs/acs-25.html]
- Other impacts of redesigning the road are the potential effects on freight movements:
  - Less road capacity dedicated to freight movement would normally mean more congestion and slower freight vehicles
  - However, if more journeys are undertaken on S lanes and MS lane, with some of those also being cargo bikes, then this transfer of users away from the HS lanes has the potential to free up freight movements, i.e. less cars on the road holding up freight movements. [Ref: https://www.theguardian.com/environment/bike-blog/2017/mar/29/cycle- freight-why-the-bike-is-good-for-moving-more-than-people]
- There are also the safety benefits, as mentioned in section 4.4 above, of removing slower vulnerable road users out of the HS lanes. [Ref: http://peopleforbikes.org/blog/national-protected-bike-lane-week-the- infographic/]
- A large amount of transport funding comes from the freight industry:
  - A reduction in car users on the network would see more freight movements occurring, increasing the revenue stream from that sector of the transport network. [Ref: https://www.transport.govt.nz/mot-resources/transport-dashboard/2-road-transport/rd075-national-land-transport-fund-revenue]

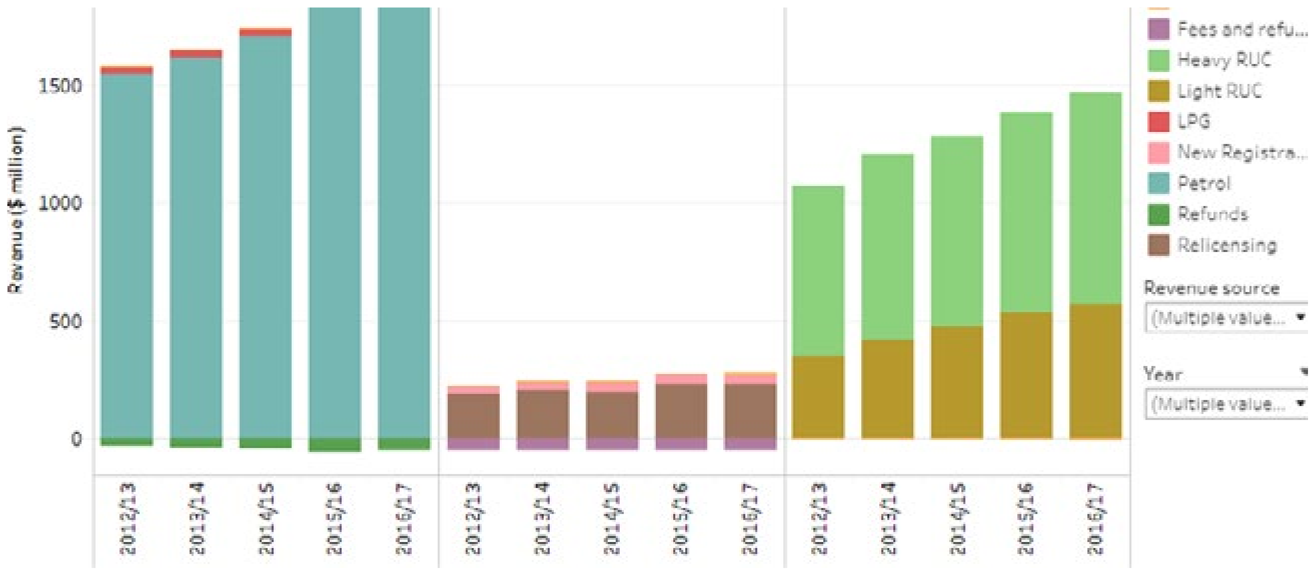

Figure 6-43: NZ land transport funding profile. (Source Waka Kotahi, NZ Transport Agency)

- Road funding is going to become an issue in many municipalities as the fuel excise taxes reduce due to electric vehicle uptake. Some countries are already preparing for this situation by instigating distance-based taxation for motor vehicles and funding out of local ground rates. This issue is multi- faceted and will not be dealt with here.

- The cost of creating S lanes and MS lanes is likely to be at the low end of the spectrum as the axle loads are vastly lower than those of heavy vehicles. Therefore, construction costs would be much less, and the ongoing, long-term pavement maintenance would also be much cheaper.

Further research

9 Further research

At the time of writing, the Covid-19 lockdowns were in full swing across the globe. To develop these road redesigns further, more research is required into:

- The potential growth of Micromobility uptake?
- What space requirements are expected and practical for Micromobility users to feel comfortable?
- What are the space and speed limits that should be applied to S lanes?
- What are the legal ramifications of changes to existing road rules?
- User surveys in pilots to determine the LoS assumptions made in section 5.2.
- What intersection designs work the best for S and MS lane?
- What is the effect of weather on the uptake of Micromobility?
- Are there planning or economic effects which need to be considered?
- Are there potential lane markings and lane separators that could be relocated based on long-term user volumes and changes in time-of-day demands?

Conclusion

10 Conclusion

The current road rules and vehicle classifications are no longer appropriate for the multitude of new mobility options entering the transport market. Consequently, road design rules and guidelines urgently need updating to reflect this new reality.

Many cities are creating active-mode and bus lanes as a response to congestion in cities. The author proposes that these areas should be reimagined as part of a speed flow continuum of movement, that is not transport mode specific.

The author is looking at changing the way laws are written and creating design guides to accommodate these new and old transport modes within the road corridor. This will improve the safety and efficiency of the transport system.

These design guides could be adopted by governments and designers for new roads, and would also contain advice for conversion and upgrade of existing roads.

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