SUSTAINABILITY IN MUNICIPAL ROAD ENGINEERING

A look at sustainable engineering practices within local government across North America

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2016 Municipal Engineering Foundation Study Tour USA & Canada

2016 Municipal Engineering Foundation Study Tour of USA & Canada

Municipal Engineering Foundation Victoria

Golden Plains Shire

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To all the organisations we visited during the tour, thank you for your generous hospitality. The welcome we received from everyone we visited, without exception, truly exceeded any expectations I had and without this support there could be no tour.

And finally to my wife for encouraging me to apply in the first place. Without your support I would never have ended up on the 2016 study tour.

Background

The Municipal Engineering Foundation Victoria (MEFVic) makes available an annual overseas study tour scholarship to selected engineers working within local governments in Victoria. This year the study tour provided for the recipients to travel to the United States and Canada and to attend the 2016 American Public Works Association (APWA) Public Works Exposition (PWX). The tour itinerary is shown below:

Figure 1: Study Tour Itinerary

1. San Francisco, California
   August 15th – City of Berkeley
   August 16th – City of Oakland

2. Portland, Oregon
   August 18th – First Stop Portland, Portland State University
   – Oregon Metro
   – Trimet
   August 19th – Portland Bureau of Transportation

3. Seattle, Washington
   August 22nd – City of Tacoma
   August 23rd – Greenroads

4. Vancouver, British Columbia
   August 25th – City of Richmond
   August 26th – City of Vancouver

5. Minneapolis, Minnesota
   August 28th-31st – APWA PWX
   September 1st – City of Minneapolis
   September 2nd – Hennepin County

Study Group

Mark Varmalis
Director Environment & Engineering
Yarra Ranges Council
MEFVic Trustee and Tour Leader

Debbie Leeson-Rabie
Assistant Manager City Works
City of Yarra
Study Topic: Service delivery models, use of technology, innovation and community engagement to provide best practice infrastructure maintenance

Bailey Byrnes
Team Leader Transport Planning
Banyule City Council
Study Topic: Embedding policy into public works through process improvement, mapping and project prioritisation

Steven Quick
Works Engineer
Golden Plains Shire Council
Study Topic: Sustainability in Municipal Road Engineering

Figure 2: Study Tour Group
L-R Bailey Byrnes, Debbie Leeson-Rabie, Steven Quick, Mark Varmalis

Executive Summary

In the municipal engineering profession there is a tendency to do things a certain way because “that’s how it’s always been done”. However, in a world where costs are increasing, resources are becoming more scarce, legislative requirements on Councils are becoming more onerous and rate capping is soon to be introduced, it is becoming imperative that Councils rethink the way in which they conduct their business. By introducing sustainable engineering practices into the municipal engineering profession we can save costs, minimise the impact on the natural environment and enhance our ability to meet the needs of the community.

Sustainability – What Is It?

Sustainability is a very complex and comprehensive issue. There is no singular definition of sustainability. However, almost all definitions agree that sustainability is comprised of three important pillars, being:

- Economical
- Ecological
- Societal

For anything to be considered truly sustainable, it must cover all three areas.

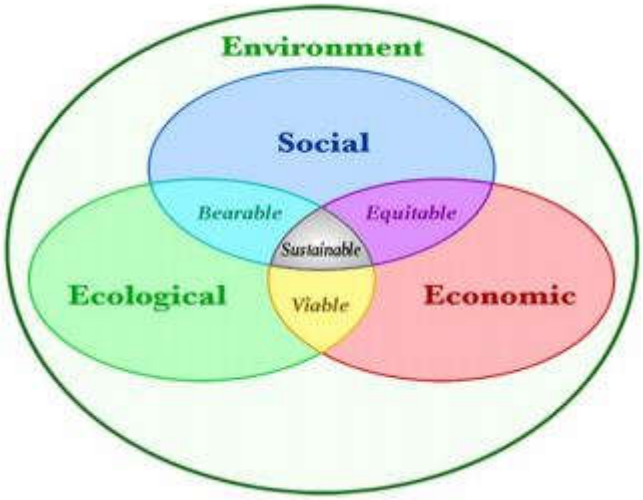

Figure 3: Sustainability Venn diagram[1]

Road Infrastructure Sustainability

In terms of road infrastructure, sustainability results in numerous benefits including, but not limited to:

- Longer serviceable lives of roads;
- Reduced construction costs;
- Reduced maintenance costs;
- Reduced negative impact on environment;
- Increase in recycling;
- Lower emissions and fuel consumption;
- Improved quality of roads;
- Improved rideability;

Section 1: Economy

There was a common theme across many of the government organisations that we visited throughout the study tour. In the early 2000's when the economy was going strong many organisations put a strong emphasis on growth and new infrastructure projects at the expense of maintenance and renewal. Governments by their very nature work in a strong political environment, and new projects are always going to win more votes than maintenance activities. You won't see a politician do a ribbon cutting on a pavement rehabilitation project.

However, when the global financial crisis hit around 2007-09, funding became much harder to come by. The combination of stagnant, or in some cases decreasing funding, and a history of neglect in terms of maintenance activities, many North American road authorities were faced with road networks that were rapidly deteriorating in condition. There are strong parallels between this scenario and what Victorian local government organisations are now facing with the introduction of rate capping.

The answer to this problem is strong asset management.

Road authorities in North America grade the quality of their road pavements in terms of a pavement condition index (PCI). The PCI is a national standard and takes into consideration distresses within the pavement, including distress type, severity and quantity.

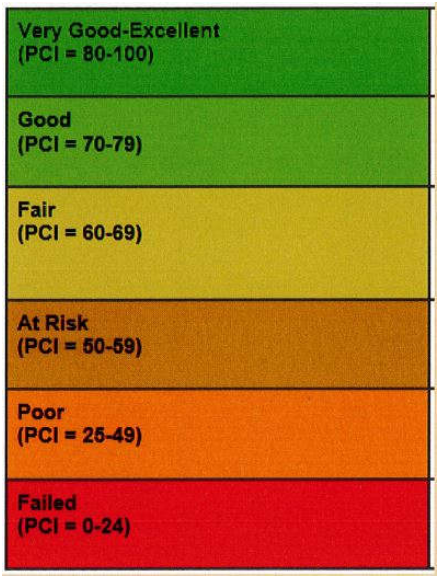

Figure 4: PCI Table[2]

Another common theme we experienced was that it was standard practice to focus spending on the roads with the lowest PCI, a philosophy succinctly summarised as: "*Worst-first*".

While this may intuitively seem like a practical solution to repairing and maintaining your road network, it is in fact economically inefficient. Due to the high costs of full road reconstruction, and the limited funding available to many road authorities, this methodology can lead to a decrease in overall network PCI and an increase in deferred maintenance (backlog).

Instead, road authorities must aim to use "the right treatment at the right place and at the right time, using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet road user expectations"[3]. In simpler terms, we need to focus on pavement preservation before it

deteriorates into a very poor condition and requires full reconstruction. This is illustrated in the pavement life cycle graph below:

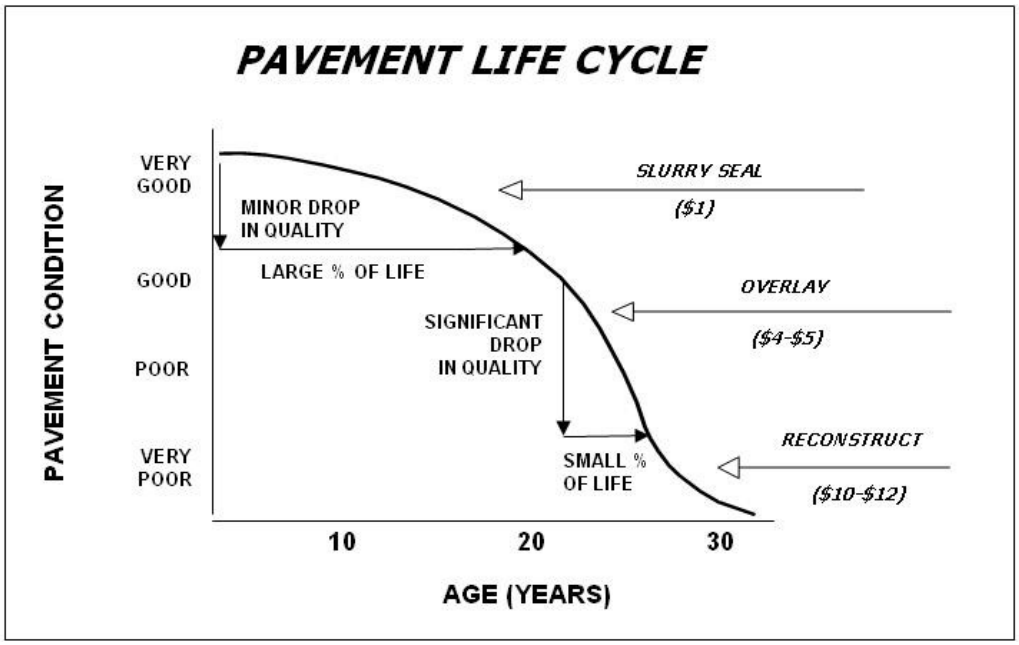

Figure 5: Degradation Curve[4]

As we can see from the graph, there is very little decrease in pavement condition in the first 15 to 20 years of pavement life. At this point in time you can undertake preventative maintenance activities, such as slurry sealing or micro surfacing works to improve the road to near new or very good condition. However, if you were to wait only a few years more there is a significant drop in quality in a short period of time, and the costs of rehabilitation or reconstruction can increase tenfold.

Recommendation

Develop and implement strong asset management policies with a focus on preventative maintenance and rehabilitation.

Case Study: Dedham, Massachusetts

Population: 25,000
Area: 11mi^2 (28km^2)
Road Network: 110 centreline miles (176km)
Average PCI (2007): 70
Deferred maintenance: US$23,652,204

Figure 6: Map - Dedham, Massachusetts

In 2007 Dedham identified a problem. It was entirely reliant on state funding for road maintenance activities and this funding was insufficient. As a result, the road network was deteriorating at a rate faster than it could be repaired. In response to this, Dedham engaged a consultant to undertake a full network pavement evaluation and to develop a prioritised works programme. The goal of the programme was to increase the average PCI from 70 to 80 over the following ten years (by 2017).

Some of the strategies employed to help improve average PCI are explored below:

Works Prioritisation

As we have already seen, there are significant benefits in prioritising preventative maintenance and minor rehabilitation works. To use an analogy shared by Joseph Flanagan, Director of Public Works, Dedham, "it is cheaper to change the oil every 3,000 miles than it is to change the engine every 30,000 miles".

Alternative preventative maintenance techniques

Dedham employed the use of an ultrathin bonded wearing course over roads that were failing sooner than expected. This was a shift from previous practices such as localised repairs and crack sealing. In doing this, the roads returned to a full 20 year service life for a relatively low financial outlay.

Alternative rehabilitation techniques

In August 2008 the Global Warming Solutions Act was passed. This requires a reduction of greenhouse gas emissions compared to the 1990 level of 25% by 2020 and 80% by 2050. This led to a number of road authorities, including Dedham, to explore the use of warm mix asphalt. There are many environmental benefits to using warm mix asphalt which we will explore in greater detail in Section 2: Ecology. There are also structural benefits to using warm mix asphalt, including decreased oxidation and better compaction, which in turn extend the life of the pavement.

Improving contract specifications

While undertaking the programme, engineers identified some recently constructed roads were deteriorating faster than expected. It turned out that the contractors had technically complied with the specifications provided, however those specifications were not robust enough to guarantee an adequate result. Therefore, contract specifications were reviewed and amended to ensure quality

outcomes. This included better road designs, appropriate lot sizes, improved quality control and contractor incentives and disincentives for works provided.

Recommendation

Review existing contract specifications and update as necessary to ensure project requirements are met.

Seeking alternative funding sources

Although more funding is not the sole solution to improving the road network, it was identified that being solely reliant on state funding was unsustainable. Therefore, the consultants worked with Dedham to help secure alternative funding sources.

The Results

Dedham was able to achieve their goal of an average PCI of 80 four years ahead of schedule. Furthermore, future predictions show an expected increase of average PCI to 91 by the year 2020.

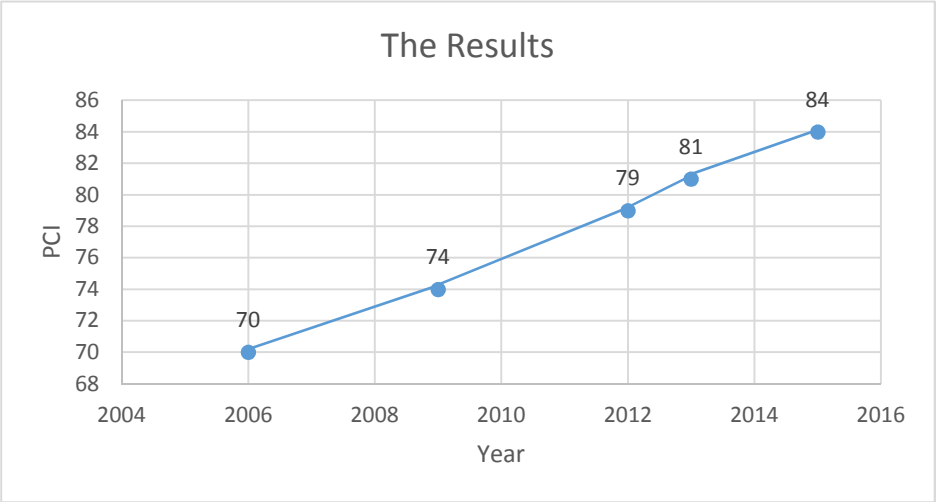

Figure 7: Dedham Measured PCI 2006-15

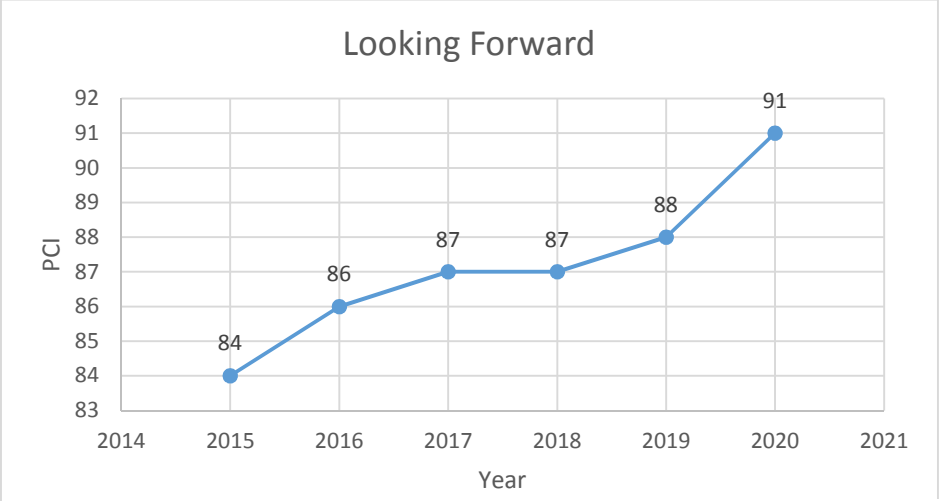

Figure 8: Dedham Projected PCI 2015-20

To further illustrate the success of Dedham's pavement management program we can compare the year the program began in 2007 to 2015:

Deferred maintenance

2007: US$23,652,204
2015: US$10,192,000

Maintenance requirements

2007: 17% of roads were deemed to require no maintenance
2015: 53% of roads were deemed to require no maintenance

By implementing an effective pavement management programme, Dedham have managed to take a road network that was deteriorating over time and without significant additional funding been able to improve the overall condition of its infrastructure.

Section 2: Ecology

Road construction and maintenance activities can have a large negative impact on the environment. These impacts include, but may not be limited to, increased greenhouse gas emissions from construction activities and from transportation usage, increases in air pollution and water pollution from stormwater runoff.

In a city such as Oakland, transportation and land use (including vehicle emissions) are responsible for 51% of all core greenhouse gas emissions within city limits[5]. In 2013 this was equivalent to over 1.4 million metric tonnes of carbon dioxide equivalent (MT CO2e). When you consider consumption emissions, that is lifecycle greenhouse gas emissions including those required to produce, transport and dispose of goods, this figure increases to over 1.7 million MTCO2e.

It is essential that road authorities try to minimise these adverse environmental impacts wherever possible. And one of the most effective ways of doing this, without necessarily adversely impacting on the costs or quality of the road network, is to employ the age-old adage of reduce, reuse and recycle.

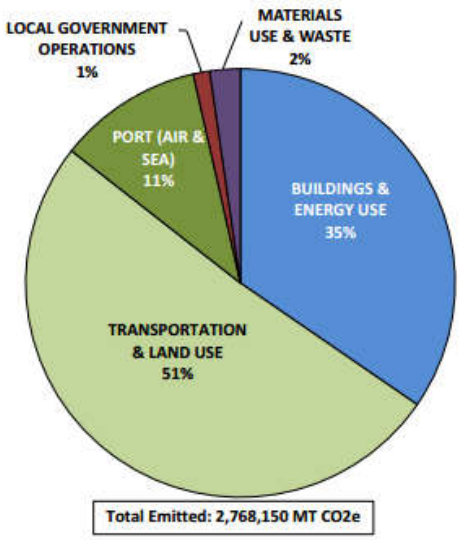

Figure 9: Oakland Core Emissions Summary 2013

In the context of road construction and maintenance activities, we can minimise the adverse impacts on the environment in many different ways:

Recycled Aggregates

Extractive resources are limited and many municipalities, including Golden Plains Shire Council, are likely to be faced with a shortfall in the future. One way of addressing the risk associated with a scarcity of gravel and crushed rock is using recycled materials such as crushed concrete, crumbed rubber, glass and other waste products as alternative road aggregate materials. The ecological benefits include a reduction of waste to landfill, a reduction in resource consumption (including quarrying activities) and often a reduction in greenhouse gas emissions. In fact, studies in the US have indicated that use of recycled materials can reduce global warming potential by up to 20% while increasing whole of life costs by 21%[6].

This practice is becoming more prevalent within the road construction industry as evidenced throughout our tour of North America.

In Tacoma we heard from Erik Sloan, Pavement Manager, and how the City of Tacoma is increasing the amount of crushed concrete used in their road pavements. The crushed concrete has comparable costs to standard materials but has the added benefit of observed improvements in compaction. This allows for a reduced thickness in the pavement layer.

At the City of Minneapolis we heard from Larry Matsumoto, Paving Engineer, who detailed how the City's concrete crushing facility has produced 3.2 million tonnes of crushed concrete since 1976 (or an average of approximately 80,000 tonnes every year). That is 3.2 million tonnes of concrete that may

otherwise end up in landfill. It is also 3.2 million tonnes of material that has been used instead of quarried rock or gravel.

Figure 10: Crushed Concrete, City of Minneapolis

Reclaimed Asphalt Pavement (RAP)

RAP greatly reduces the amount of asphalt required to undertake road construction and rehabilitation activities. It involves the removal of asphalt pavement by milling and is then either transported for processing before being re-used or is pulverised on-site and incorporated within the base layer of the road. It is becoming more widely used within road authorities, and is in fact, considered to be the most heavily recycled construction waste product in many countries[7].

Warm Mix Asphalt (WMA)

Another technology gaining popularity across North America is WMA. WMA is similar to typical hot mix asphalt (HMA) but incorporates the use of additives to help lower the workable temperatures. Standard HMA is placed at approximately 160°C whereas WMA is generally placed around 120°C. The main environmental benefit of using WMA over HMA is the significant reductions in emissions such as carbon dioxide as illustrated in the graph below[8]:

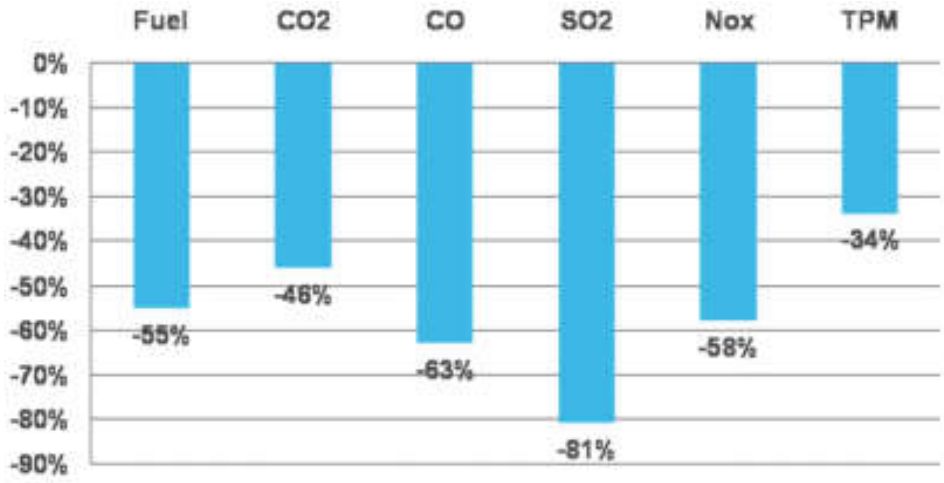

Figure 11: Emissions - WMA vs HMA

Another major benefit to using WMA is that it often increases the serviceable life of the road. The lower mixing temperatures cause reduced oxidation of the binder. This results in a more flexible binder reducing cracking in the pavement. The lower temperatures also allow for more time to roll

and compact the road. This results in a better, more even compaction, which in turn extends the pavement life.

Another upside to using WMA is that it facilitates use of higher percentages of RAP compared to HMA. There has been demonstrated success in the US with RAP content as high as 50%[9].

One final benefit that is worth noting is associated with occupational health & safety. Not only is it safer working with a material that is cooler, but workers are exposed to significantly less harmful fumes during the process.

Recommendation

To help promote use of WMA, or other sustainable technologies, offer incentives to contractors to use these products.

So how do we do it?

We do this through strong policy making. This was another common theme we observed throughout the study tour. The majority of cities we visited had minimum requirements for use of RAP and/or other recycled materials to be used in their projects and, in addition to this, most cities were looking to increase this minimum as mix designs improved. For example:

- Berkeley's ordinances state that 70% of all waste products coming out of a project must be recycled.
- The City of Oakland requires a minimum of 15% recycled material in all pavement works (looking to increase to 25%).
- Trimet, Portland has a policy that states that 90% of all purchased materials are to be recycled.
- The City of Vancouver requires a minimum of 20% RAP to be used. They are also researching new mix designs with the view of increasing this to 35% in the future.
- The City of Dedham, Massachusetts, who presented at the 2016 APWA PWX, requires a minimum of 15% RAP to be used in road projects.

Figure 12: City of Berkeley.
Car park demolition with most waste products being recycled and repurposed

These are just a few small examples of how Cities are ensuring that they are helping to minimise the negative impacts of building and maintaining their road networks. By implementing policies such as these they are also ingraining an environmentally conscientious culture within their organisation which is vital in the ongoing pursuit of sustainability.

Recommendation

Develop policies which promote recycling and stipulate minimum requirements for recycled content.

Case Study: City of Vancouver

The City of Vancouver is taking things a step even further. While visiting the Kent asphalt yards that service the City of Vancouver we learnt about a number of innovative and environmentally friendly initiatives. One such initiative was the use of a wax made from recycled plastics in their WMA. This wax is the additive used in the asphalt process which enables it to be worked at lower temperatures. Typical waxes are made from gasoline or diesel products, so incorporating recycled plastics in this process has significant environmental benefits. It also facilitates the use of a high RAP content, in the order of 20-25%. The first trials of using recycled plastic wax in WMA commenced in 2012 and so far both the performance and costs are comparable with a typical HMA with RAP blend. Vancouver has been trialling other products as a substitute for the wax, such as soya wax which is sourced locally. According to Jeff Markovic, Manager Kent Services, there has been success in using the soya wax product.

Figure 13: Kent Asphalt Yard

Case Study: Greenroads

Our visit with Greenroads was fantastic in highlighting that 'green' projects don't necessarily cost more and, in some instances, can help result in significant cost savings.

Although we were not lucky enough to visit this project, Dr Jeralee Anderson, Greenroads, shared with me the Hacienda Green Street Improvement Project. The project scope included street narrowing, water sensitive urban design, installation of footpaths and dedicated bike lanes as well as reconstruction of the roadway using full depth recycling (FDR).

It's the first project to use FDR for pavement construction, reusing 80% of existing materials and resulting in savings over the conventional construction practices of 50%, approximately US$2 million.

Figure 14: Hacienda Green Street Improvement Project[10]

As technologies improve and whole of life testing is being undertaken, these alternative options are becoming not only more viable within the industry, but in many instances preferable to standard practices.

Section 3: Society

Roads are an essential part of life. They facilitate transportation for many classes of road user and are essential in keeping communities connected. Most of us rely on them to get to work, to school, to do the shopping. But they do incur social costs. These can include traffic congestion, the risk of accidents occurring, financial costs to the community (through, for example, fuel costs) and decreases in community health and wellbeing through enabling more sedentary lifestyles.

Probably the most obvious solution to reduce these societal costs is to reduce the volume of traffic on our road network. Less cars on the road mean less congestion. It can lead to reductions in accidents. There is less reliance on fuel and people will lead a more active lifestyle.

However, we live in a world that seems obsessed with continual growth. Reducing traffic volumes on the road network is an immense challenge, but it can be done. To help illustrate ways in which we can achieve this, we should look to cities that have been fighting this challenge for years.

Case Study: Portland Transportation

The City of Portland has a population of approximately 600,000 residents. However, by the year 2035, census data predicts this to rise to 860,000, with an increase in jobs of 140,000. According to Tom Hughes, Oregon Metro Council President, some studies have indicated that Portland is the most congested city in the entire United States (based on a percentage of time during a given commute being stuck in congestion). Simply speaking, the City of Portland's road network does not have the capacity to support this level of growth if everyone drives a car. This can be expressed in terms of a "trip gap", as illustrated below:

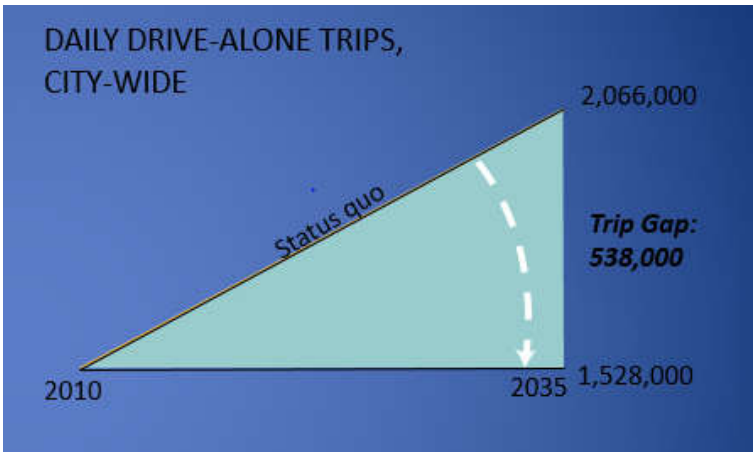

Figure 15: Portland Trip Gap[11]

In this diagram we can see that the 2010 level of daily drive-alone trips was 1,528,000. If nothing is done to minimise traffic volumes this is predicted to increase to 2,066,000 by 2035. In other words, there is a trip gap of 538,000.

Portland is attempting to address this gap through the idea of a "20 Minute Neighbourhood". The idea behind this concept is that everything you need should be available within 20 minutes of your home, facilitating a more balanced transportation system. By supporting key public places and offering more transportation options for short trips, such as walking, biking and public transport, they are reducing

the need for driving. They are promoting centralised growth around stops on their transit networks. This effectively creates 20 minute neighbourhoods at each stop along the transit route.

Other strategies utilised by Portland Bureau of Transportation (PBoT) include prioritising freight trips, promoting car-share services and increasing the numbers of people who are working from home.

So are these strategies actually working? We have seen that Portland have put a strong emphasis on promoting walking, cycling and transit as transport options. But has this resulted in less traffic, or a reduction in their trip gap? Thankfully, PBoT have the metrics in place to help us answer that question.

As it turns out, these strategies are predicted to reduce the trip gap by 475,000 as illustrated below:

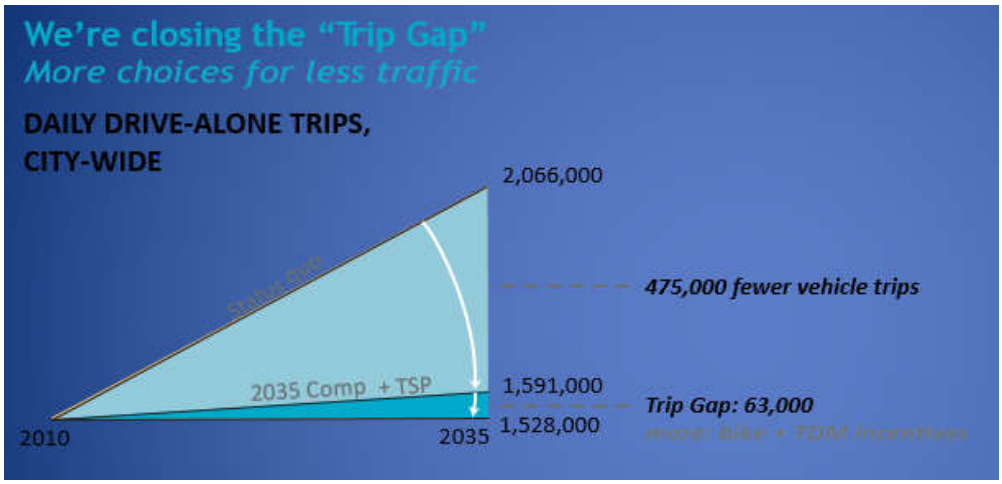

Figure 16: Projected Portland Trip Gap 2035[12]

We can go one step further and identify the change in commuter use by individual mode of transport. The change in mode (comparing 2000 to 2013) is shown below:

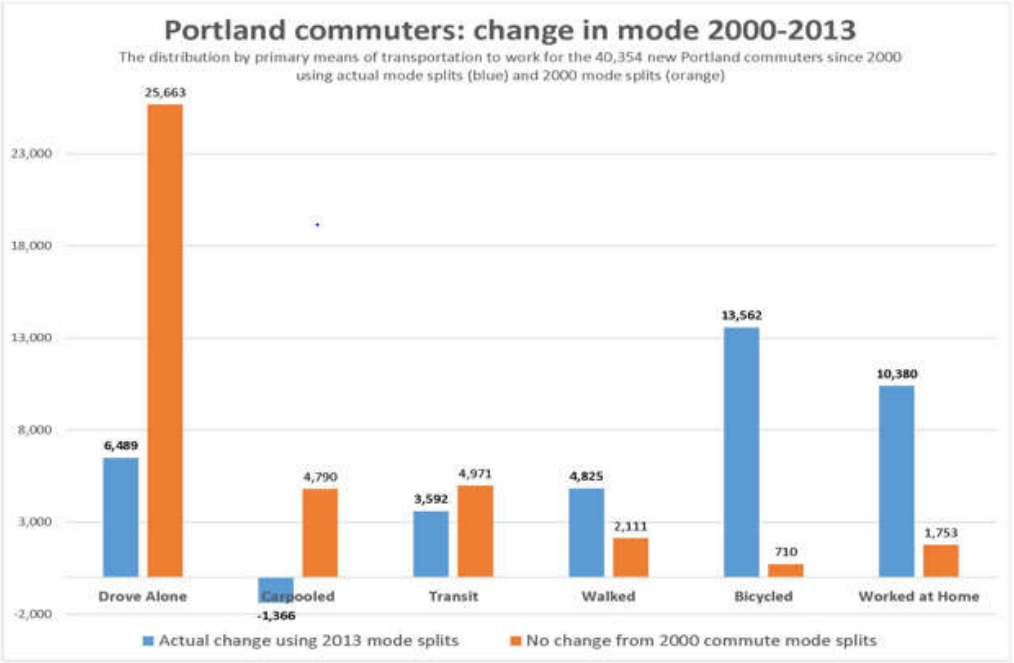

Figure 17: Portland commuters change in mode 2000-2013[13]

This shows us that there has been a significant drop in the predicted rise of drive-alone trips, as well as smaller drops in car-share and transit. Meanwhile, walking, cycling and working from home have all increased dramatically.

One of the biggest success stories to come out of this has been the Safe Routes to School Programme. 43% of all of Portland's school students (K-8) commute to school through active transportation. This is the highest level in the US and is significantly higher than the national average of 11%[14].

Portland Safety

According to the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS), there are approximately 30,000 fatalities on roads within the United States every year. To put that in perspective, that is one and a half times the entire population of the Golden Plains Shire Council, dying on US roads every single year.

Portland has adopted Vision Zero as an official policy in 2015. This program has been adopted by many cities worldwide and aims to eliminate fatalities and serious injuries on the road network within the next ten years[15].

There are strong parallels between this program and the Traffic Accident Commission's (TAC) Towards Zero campaign in Victoria. These parallels highlight the need for introducing robust policies within government to help address issues such as fatalities on our roads.

One death on our roads, is too many.

Funding

One final point of interest is how PBoT receives funding. There are two major funding sources for the Bureau, being the gas tax and parking metres. By actively reducing the growth of the number of cars on the road, and resultantly the amount of parking within the city, they are potentially adversely impacting on their revenue stream. Therefore, they are forced into identifying alternative funding streams, such as public investment.

Recommendation

Develop policies to help diversify transportation usage and minimise reliance on vehicular transportation.

Case Study: Vancouver Transportation 2040

A similar paradigm shift is occurring in Vancouver. Studies have shown that Vancouver is the most congested city in Canada and commuters can spend up to 30% longer in their commute due to traffic congestion[16]. Historically, like many North American cities, Vancouver has had a strong reliance on cars as the primary mode of transportation. The following charts illustrate the reliance that Vancouver has had in the past, with as much as 90% of all commutes being by car, while also highlighting an increase in active transportation and transit[17].

Figure 18: Vancouver Historic Transport Modes

Vancouver's Transportation Plan 2040 has set targets to increase the number of trips made by active transportation and transit to at least 67% by the year 2040[18].

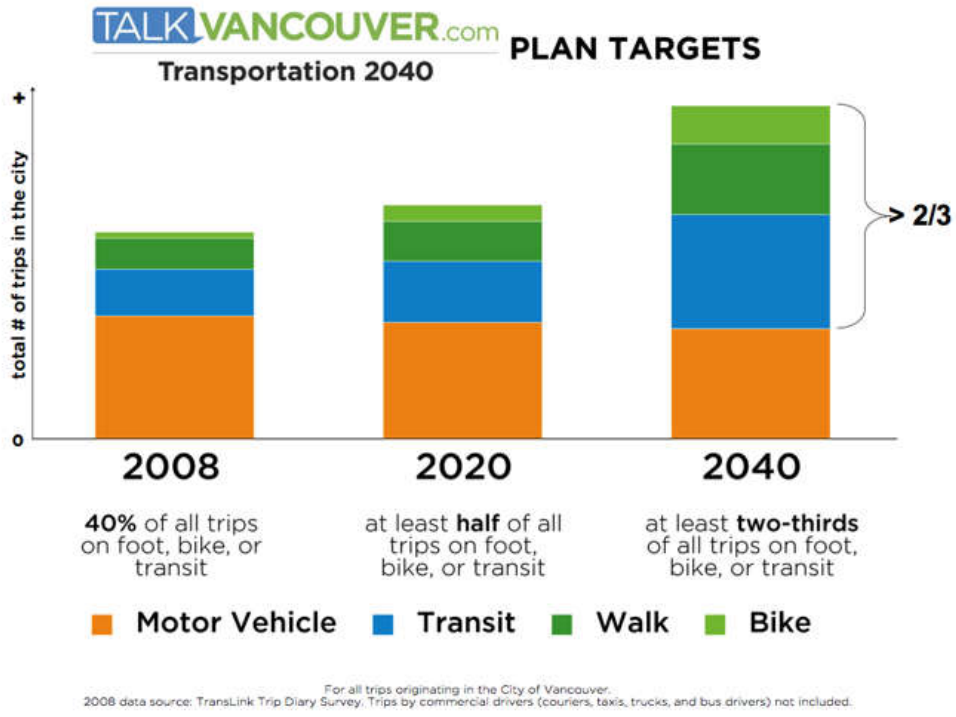

Figure 19: Vancouver Transportation 2040 Targets

One of the fundamental concepts of achieving this is a "hierarchy of modes". In other words, it prioritises active transport and transit above cars. It also recognises the need to move goods and services, in addition to moving people. The hierarchy of modes is as follows:

1. Walking;
2. Cycling;
3. Transit;
4. Taxi, Commercial & Shared Auto;
5. Private Auto.

Vancouver Safety

Similar to Portland and Victoria, Vancouver has also incorporated a zero fatality safety target within their Transportation Plan. It recognises the risks associated with vulnerable road users as illustrated below[19]:

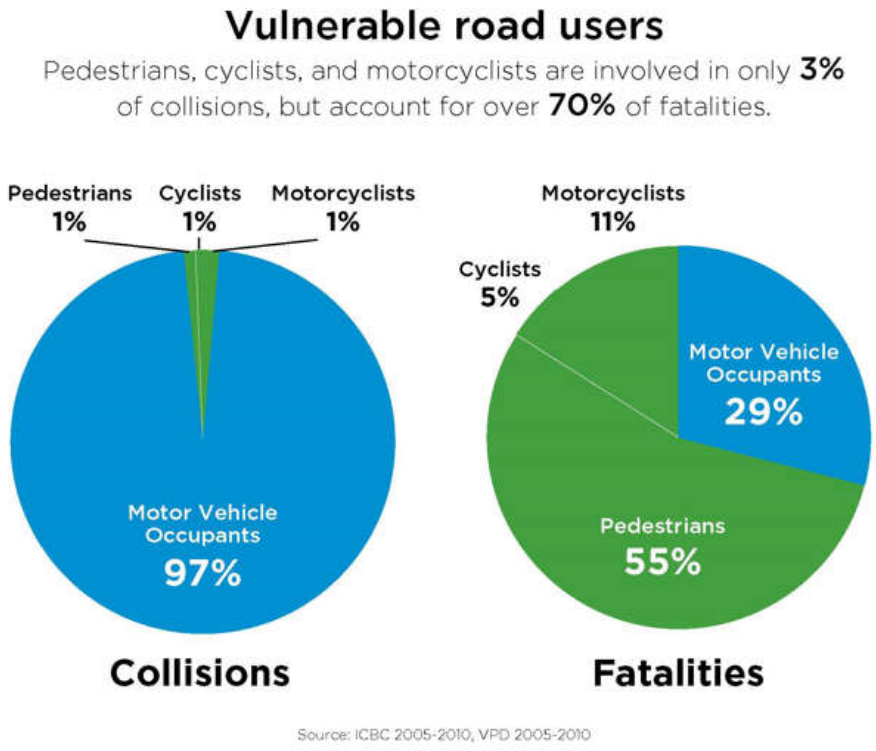

Figure 20: Vancouver Traffic Accidents by Mode

The zero fatality target is admittedly an aspirational target. Like many developed countries, the fatality rate in Vancouver, and Canada as a whole, has been steadily decreasing, however there is a long way to go before it reaches zero. But by having the goal entrenched within your policies, it commits government organisations to liaising with stakeholders to examine the main causes contributing to road accidents and fatalities. It helps facilitate the processes to take in response to identified risks. These responses may not be solely reliant on engineering solutions but may also incorporate education and enforcement as a means to reducing traffic accidents.

Recommendation

Prioritise projects that have a strong focus towards safety, especially for vulnerable road users.

Recommendations

1. **Develop and implement strong asset management policies with a focus on preventative maintenance and rehabilitation.**

2. **Review existing contract specifications and update as necessary to ensure project requirements are met.**

3. **To help promote use of WMA, or other sustainable technologies, offer incentives to contractors to use these products.**

4. **Develop policies which promote recycling and stipulate minimum requirements for recycled content.**

5. **Develop policies to help diversify transportation usage and minimise reliance on vehicular transportation.**

6. **Prioritise projects that have a strong focus towards safety, especially for vulnerable road users.**

Conclusion

Throughout the tour, and detailed within this report, we have explored some of the sustainability challenges faced by municipal governments in the areas of economy, ecology and society. We have examined various strategies we can implement in response to these challenges. It should be understood that sustainability within municipal road engineering is a broad subject with diverse and wide ranging issues. This report is not meant as an exhaustive review that has solutions to all of these issues, however it is hoped that it provides some guidance and inspiration on what can be achieved through effective asset management, innovative engineering solutions and robust policy making.

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