Municipal Engineering Foundation Victoria

MANNINGHAM

SMART CITIES – SMART MAINTENANCE AND ASSET MANAGEMENT OF KEY INFRASTRUCTURE

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2019 Study Tour Report

1. Forward & Acknowledgments

This report has been made possible through the generous support of the Municipal Engineering Foundation Victoria (MEFV). The MEFV provide scholarships to professionals in the public works industry, generally to three selected participants each year to undertake a study tour to the United States and Canada. The intention of the scholarships is to provide the selected individuals with an opportunity to build and develop their personal and professional skills, while researching and collecting information relevant to their chosen study topic, which ultimately is included within this report. The learnings brought back from the tour assist our industry through the sharing of knowledge from other organisations.

The tour was organised by the tour participants with support from the MEFV. Six cities through the United States and Canada were chosen based on the participant's chosen topics of study and prior research undertaken by the team. The following cities were visited by the team:

- Vancouver, Canada
- Portland, Oregon, USA
- Seattle, Washington, USA
- Chicago, Illinois, USA
- Boston, Massachusetts, USA
- Denver, Colorado, USA

The itinerary was further refined by the team through engaging with agencies and utilising existing contacts established through the MEFV and APWA, as well as further research.

A significant part of the tour was the American Public Works Association (APWA) Public Works Exhibition (PWX) in Seattle. The itinerary was developed around this event. The team developed the itinerary to schedule the conference into the second week of the study tour, which ran from Sunday morning 8th September until midday Wednesday 11th September.

The successful scholarship recipients and tour participants, including chosen topics of study and the short summary shared with organisations visited are as follows:

- Lachlan Johnson, Manager Maintenance & Operations – City of Port Phillip
    - Technological innovation in local government

A goal of the study tour is to examine how technological innovation can help Port Phillip continue to provide an amazing place to live and work in the face of the significant population growth it faces in the future. Of particular interest are Smart City initiatives and technologies that are helping infrastructure work more efficiently as well as innovative technologies for infrastructure design and management such as Building Information Modelling and Digital Engineering.

- Tony McGann, General Manager Infrastructure & Leisure Services – Colac-Otway Shire Council
    - Asset management leading into long term financial Planning (LTFP) and community engagement to help Councils make the tough decisions

    Colac Otway's biggest challenge is to set up for long term financial sustainability. To do this we need to improve our asset management and we need to give our Councillors the information they need to make strategic decisions which will often be hard to make. We need to better engage with our community so that they can have input into service levels, understand the costs that flow from those service levels and the choices the Council is faced with. The goal of this study tour is to investigate innovative international approaches to engagement and asset management.

- Kurt Pitts, Coordinator Roads & Infrastructure – Manningham City Council
    - Smart Cities – smart maintenance and asset management of key infrastructure

    The objective of this study topic is to investigate various Smart City technologies and initiatives with the aim of assisting Manningham City Council and other Victorian municipalities with the management of key infrastructure through improved methods of maintenance and asset management. Of particular interest is innovative technology and collaboration with autonomous vehicles, as well as opportunities for smart sensors within key infrastructure

- Warren Roberts, Chairman – Municipal Engineering Foundation Victoria
    - Tour leader and mentor

Sincere thanks must go to all trustees of the MEFV, in particular: Chairman Warren Roberts, Geoff Glynn and Merv Paton for their support and assistance through the preparation and participation in the tour. Tour Leader, Warren joined the group for the Seattle and Chicago part of the tour, attending PWX with the team. His leadership, mentorship and experience was highly

valued by the team and greatly benefitted all. Geoff provided a mentor role with great assistance having participated as tour leader the previous year, as well as facilitating many of our meetings. Merv went above and beyond for the team, assisting with arrangement of flights and accommodation, and many other behind-the-scenes tasks. Without the generous support of these amazing volunteers, opportunities like this would not be possible. We in Victoria are extremely fortunate to have sponsorship though the MEFV available to us, enabling such scholarships.

The generosity of the Foundation is highly valued within the industry in Victoria.

Thank you must also go to my employer, Manningham City Council, for supporting my participation in the study tour including my time away from the office.

Sincere thanks must also go to my fellow study tour grant recipients: Lachlan Johnson and Tony McGann. The discussions we had together throughout the trip, and particularly during our daily debriefs were immensely valuable. The teamwork and camaraderie experienced throughout the duration of the trip will be remembered and forever treasured.

Organisations Visited

During our time in the US and Canada, a large number of organisations took time out of their day to prepare a meeting and presentation, and host our team. These organisations provided great hospitality, often originating from a random email from the other side of the world. The generosity that these organisations showed our team was inspirational, and greatly appreciated.

The following list details the organisations that the group visited during the tour. Each organisation provided the team with amazing hospitality and were very generous with their time.

Vancouver, British Columbia, Canada

- City of Vancouver
- Vancouver Port Authority
- City of West Vancouver

Portland, Oregon, USA

- City of Portland
- City of Oregon City
- WES Tri City Treatment Plant

Seattle, Washington, USA

- APWA PWX

Chicago, Illinois, USA

- Village of Oak Park
- City of Elmhurst
- Collaborative: Villages of Bensenville, Woodbridge & Lombard
- Village of Lake In The Hills
- APWA Chicago Chapter
- APWA Fox Valley Branch

Boston, Massachusetts, USA

- City of New Bedford
- City of Boston
- Town of Wakefield

Denver, Colorado, USA

- Panasonic CityNOW / Easy Mile
- Town of Castle Rock
- National Renewable Energy Laboratory (NREL)
- City & County of Broomfield
- APWA Colorado Chapter

The generosity provided to the team from all organisations visited was enormous, and greatly exceeded the team's expectations.

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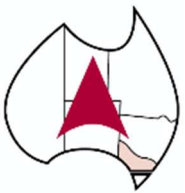


2. Executive Summary

“Smart Cities” is a relatively new term within the industry. Stemming from our need to better manage our assets, the industry is looking towards smarter ways to gather data from key pieces of infrastructure, and in turn plan for maintenance and renewal of these assets. Increased pressure on municipalities with rate capping and changing demographics has encouraged municipalities to look to technology as a means to assist in reducing operating costs. Smart Cities technology includes a combination of cutting edge technology, and sensors to gather data and information.

So what is it exactly? A Smart City is generally an urban area (a municipality, a city, a village, a suburb, etc) utilising different types of electronic sensors to gather data. The data is then used to assist the organisation or managing body to manage and maintain assets more efficiently and effectively. Smart technology is utilised to analyse and manage this data, which can be sourced from sensors in road pavements, traffic lights, and other infrastructure, which can collect data and information from the atmosphere including personal devices, vehicles, people, as well as many others. Smart Cities generally use a multitude of different sensors to collect this data including but not limited to atmospheric sensors, cameras, radar, LiDAR, ultrasonic, GPS, infrared and magnets.

My topic focuses on the use of Smart Cities technology and devices to assist our industry in better managing our assets, both short-term and long-term. How can we utilise this emerging technology to assist us in the management of our infrastructure? How can we utilise this technology to reduce our operating costs, and manage our assets more efficiently? How can we utilise this technology to tell us what our infrastructure is doing, and plan and deliver our maintenance activities at the opportune time?

While alternative transport options continue to increase in popularity, the importance of support from our industry for methods such as Autonomous Vehicles (AV) & Electric Vehicles (EV), bicycles and eScooters, and public transport has never been more important.

AV is advancing quickly with the advancement in technology and Artificial Intelligence (AI). As a relatively new industry, advancements in battery technology, data processing technology, connectivity such as 5G, sensors and AI have assisted manufacturers in the development of this

technology, ultimately assisting us on the path to making AV much more accessible into the future.

The bicycle networks and infrastructure established within US cities, particularly those visited by the team in the north-west are far advanced to what we have in Australia. Similarly, the cycling culture within the US is vastly different to that in Australia. These factors have greatly contributed to the success of bike share programs across most cities visited by the team, whereas the unpopular bike share program in Melbourne failed and was scrapped by the Victorian Government in 2019.

eScooters continue to rise in popularity and supplement the bike share programs. The simplicity, cost effectiveness and availability of eScooters make these an attractive option for locals and tourists alike who wish to travel short distances, particularly around the downtown area of cities.

The benefits of these alternative transportation modes can be enormous, both to the public user groups, and to our agencies. Ensuring the appropriate infrastructure is in place prior to adoption is very important to ensure the success and prevent failure and/or negative feedback. Melbourne's Bike Share is a good example of a program failing due to lack of infrastructure, among other problems.

Thinking outside the box to create alternative transport methods has shown great success in Portland, Oregon. Two major projects – the Portland Aerial Tram and the Tilikum Crossing Bridge show how innovation and stepping outside the box can have lasting positive effects.

Innovation in Denver, Colorado is advancing in leaps and bounds. Peña Station is setting a new standard for Smart Cities and innovation, while NREL in the west of the city continues to lead the industry through research and the invention of many innovative products.

Smart infrastructure is developing at a very fast rate. Incorporating smart technology can assist us in managing our assets, and reduce costs into the future. Smart infrastructure can be utilised to assist bike share programs and eScooters, and to advance the Smart Cities principals.

Smart Cities is gaining in popularity within the industry. The possibilities with Smart Cities are enormous. Smart Cities can greatly assist the development and operation of AV, and with the assistance of AI, make self-driving cars on our streets a reality in the not-too-distant future.

Data processing and connectivity advancements greatly assist our ability to advance Smart Cities ideas and infrastructure. The birth of 5G is making an enormous difference in the industry, and as 5G becomes more widely available, we will witness a rapid advancement in the technology associated with Smart Cities.

Locally, we are beginning to see advancement in Smart Cities ideas and projects. The Victorian State Government and Australian Federal Government have developed Smart Cities grant programs, while local universities are rapidly researching various ideas. Local councils, including Manningham, are beginning to implement their Smart Cities ideas, with results beginning to become apparent.

Many great leaders were encountered throughout the duration of our study tour, and it was clear to the team that staff working with strong and empowering leaders were inspired. They had an energy and drive about them that was clearly instilled within them through organisational culture, and inspirational leadership.

Research being undertaken at NREL (National Renewable Energy Laboratory, located in Golden, Colorado) is advanced, and the organisation is leading the industry through research and advanced trials. New technological advancements such as electrochromic glass and SwitchGlaze, a switchable photovoltaic (PV) window demonstrate industry-leading research.

The importance of strong and varied leadership is critical to an organisations success, and particularly its ability to innovate and implement new ideas. As an organisation develops its ideas and desire to innovate, it must consider changing its culture at the same time. Ensuring the right mix of staff, and in particular leaders are present within an organisation will greatly improve the chances of success.

Figure 1 – The team undertaking a site tour with the City of West Vancouver

3. Key Findings and Recommendations

Throughout the study tour, many learnings were experienced as the team met with a vast array of varied organisations around Canada and the United States. Analysis of the information gathered throughout the tour, and further research and findings have allowed me to compile a number of recommendations, as detailed below, and in Section 12 of this report.

3.1 Alternative Transportation

It was evident to the team throughout the tour that bicycle infrastructure is far advanced to that in Australia in most cities visited. In particular, the north-eastern cities (Vancouver, Canada; and Portland, Oregon) had bicycle infrastructure superior to that of any city in Australia.

I. **Plan in advance to accommodate alternative transportation**

   Through master planning and project development, ensure alternative transport options are accommodated. Plan for increased bicycle and eScooter usage, and plan for future docking stations. Incorporate AV infrastructure into future planning.

II. **Plan and build for AV & EV's – build the infrastructure now, rather than retrofit later**

   Look at opportunities to incorporate EV charging stations where projects are planned, as well as improvements to allow for AV. For supermarket car park upgrades, plan for EV charging stations, and AV driving and parking. For planned works and major maintenance activities, investigate and explore how road alignments could be improved to allow for AV technology and further assist future implementation.

3.2 Smart Cities & Innovation

Smart Cities technology, although advancing fast, is still in its infancy. The majority of cities visited were undertaking trials, and continuing to research and understand the technology and trial findings. There are a number of ways an organisation can improve the chances of success when pursuing innovation and Smart Cities options.

III. **Actively seek & participate in innovation trials – engage with suppliers & industry**

   Stay abreast of industry innovation options and new products hitting the market. Thoroughly undertake your own research and ensure all information available has been

absorbed and summarised for others within your organisation (as well as the community). Seek out involvement in trials and new products. Implement on a small scale. Provide staff with sufficient time to seek out innovative ideas. Keep in touch with research institutions and industry leaders, and work together to explore trial options within your own municipality.

IV. Share innovation trials & wins – promote amongst industry & community

Share success stories through your community. The public obtain benefit from success stories, and will support further trials and innovation providing community consultation has been engaging and informative. The community are key to continued innovative success.

Write papers for magazines and conferences – share the information with the industry. Invite other municipalities to participate and witness your own innovative projects through transparent information sharing and open site visits. Provide support through your own learnings and knowledge to others in your industry; be open to sharing your own failures and how your successes have come about. Sharing of information can greatly assist innovative success stories, and allow a support network for innovation on a greater scale within the industry.

V. Continue experimentation

Stay abreast of industry information and new products. Look for opportunities for experimentation through your day-to-day role; look for better ways to achieve things, and ways to promote your business or municipality. Take baby steps, start small and focus on undertaking small-scale trials, and upon success, increase the scale for the next project or further trial. The importance of starting small cannot be overlooked – failure on large scale trials can be catastrophic and limit the organisation's ability to innovate in the future. Failure on small scale trials can be a learning point, easily rectified and improved upon. And if sold adequately through effective community consultation, further trials are more likely to be supported by the community.

VI. Recruit the right people

Recruiting staff that share your vision for innovation and smart cities is important to the success of your vision. Recruit staff for their hunger and desire to innovate and change,

for their openness and willingness to learn, rather than their overall experience alone. Seek the right staff to ensure success through innovation.

3.3 Using Smart Technology in Asset Management & Maintenance

Ensuring your agency has the capacity to process vast volumes of data, analyse and interpret this data, and present it in a meaningful way is important. Having the means within your organisation, through technology and resources will ensure you have the means for success.

VII. Develop policies and procedures to guide data capture & usage

Initiate the development of policies to guide the process of data capture. Existing policies may be utilised to establish a research base to develop your own policies, ensuring understanding. Having policies and procedures in place in advance can be beneficial to ensure consistency and greater understanding prior to embarking on smart technology projects. Providing guidance in the usage of the captured data can be equally as important to ensure there is a clear plan in place prior to beginning data capture – why begin capturing data if we don't know what we are going to use it for? Or how we are going to use it/how it will benefit us?

VIII. Establish a 'Smart City Lead' within your organisation

Identify and establish a Smart City Lead to drive the ideas, collection and analysis of data. This lead will be the driver for projects, and how the front end (smart city projects & data capture) benefits the back end (asset management data and planning). Ensure there is a need for data prior to funding and initiating a project without a purpose.

4. Background

Smart Cities is a new term, gaining in popularity in Australia and around the world. But how well are we doing here? Are we on the right track? This study tour provided the opportunity to investigate just how advanced our friends in the United States and Canada are in this space.

Prior to and throughout the tour, the team became familiar with the many similarities, as well as the many differences between the government structure and systems between Australia and the United States.

Figure 2 below illustrates the key difference in the levels of government between Australia and the United States. The addition of the County, as an additional level between State and Local Government, provides for greater governance in the community.

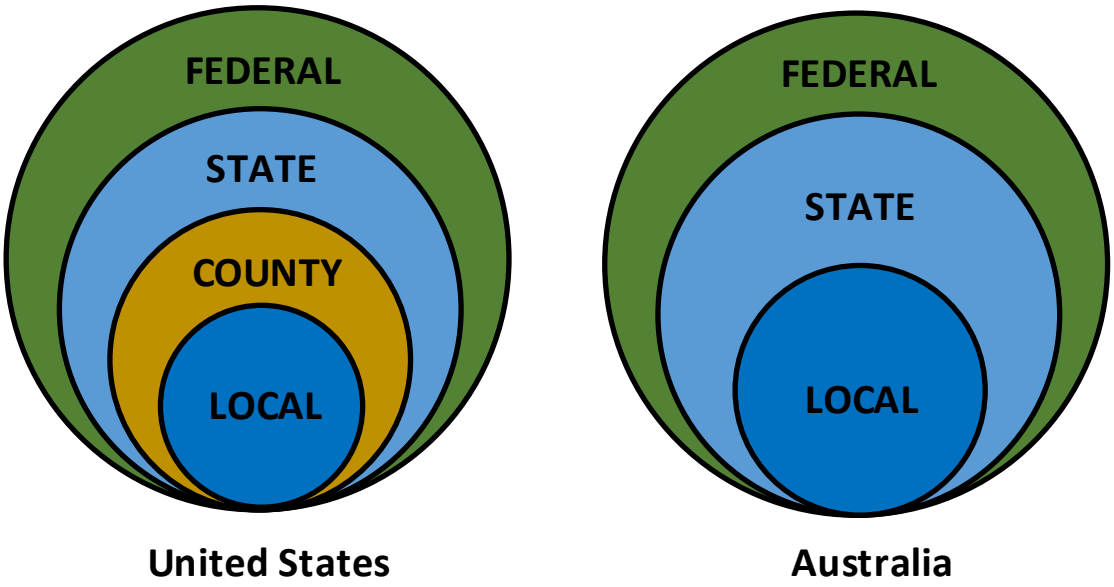


Figure 2 – Comparison – Levels of Government – USA Vs Australia

The United States is one of the oldest continuing democracies in the world. The US President is directly elected by the people, via a non-compulsory voting system, and must appoint non-members of congress to fill ministerial posts. In comparison in Australia, the Prime Minister is chosen by the elected members of the party or parties that have won a majority of seats in the House of Representatives. A compulsory voting system is utilised to elect these members.

There are many more local municipalities such as Towns, Villages, Cities in the US, and many are much smaller in size than those in Australia. The US also contains many small districts that

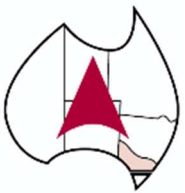
fall under the local government category such as school districts, fire or police districts, townships as well as others. The table displayed in **Figure 3** below represents the number of municipalities and other levels of government across the US and Australia. Note that the number of municipalities in the US far exceeds that in Australia. This is due to two main reasons: a much larger population in the US, and much smaller local government areas in the US. Australia contains vast areas with minimal population, while some locations in Australia have been through municipal amalgamation (most notably in Victoria in 1994, under then Premier Jeff Kennett), where the total number of municipalities has been greatly reduced. The remaining municipalities take on much larger areas than their counterparts in the US.

Governments	USA	Australia
Federal	1	1
States	50	8
Counties	3,034	0
Municipalities (City, Town, Village)	19,429	552
Townships	16,054	0
School Districts	13,506	0
Special District (utility, fire, police, Library etc.)	35,052	100
Total	**87,576**	**664**

Figure 3 – Total government numbers

Although the government structure is different between our two countries, and the size and quantity of municipalities, states and other jurisdictions varies, the fundamentals remain the same. Some large noticeable differences such as water reticulation and waste water treatment are evident. Both services are managed by local government in the United States, and generally by the states in Australia.

The main noticeable difference is the county system. While some agencies such as the City & County of Broomfield in Colorado operate as a combined entity, generally they operate separately. Counties are an additional layer of government administration, and generally manage larger duties. For example, local government undertake police duties, while counties undertake the court system and correctional system.



5. Definitions

ADA	American Disability Act
APWA	American Public Works Association
AV	Autonomous Vehicle
DARPA	Defense Advanced Research Projects Agency
Downtown	The city or CBD; main part of town or city
FBI	Federal Bureau of Investigation
IoT	Internet of Things
IPWC	International Public Works Conference
IPWEA	Institute of Public Works Engineering Australasia
NREL	National Renewable Energy Laboratory, Located: Golden, Colorado
OHSU	Oregon Health & Science University
PBoT	Portland Bureau of Transportation
PDX	Portland International Airport
Public Transit	Public Transport and the wider network
PWX	Public Works Expo
RACV	Royal Automobile Club of Victoria
Right of Way (ROW)	Road reserve
Sidewalk	Footpath
WSUD	Water Sensitive Urban Design
YVR	Vancouver International Airport

6. Alternative Transportation

Humans have been inventing new ways to move around for thousands of years. One of the earliest and largest triumphs – the invention of the wheel – occurred some 5,500 years ago, in the late Neolithic period. The wheel started as a potter's wheel to aide in the development of pottery, and shortly afterwards, was innovatively applied to lateral movement, assisting humans in the movement of goods

Similarly, there is evidence around this time of the use of wooden logs to assist the movement of large stones, generally attributed to construction (think Stonehenge and the Pyramids).

From this point in time, the existing fundamental idea of the wheel has been modified and improved upon to achieve the best outcome for the task at hand. This is evident through much of our industry today.

This human nature to strive for an easier and better way to achieve something is not new, and something humans have been doing for millennia. This is reflected through new technology and innovation in the form of alternative transportation methods.

The wheel was a solution to a problem, and assisted the people of the time with transportation of materials and goods. The original simple idea has been expanded upon and improved upon throughout the years, while keeping the fundamental principles intact.

The wheel is a great example of how we have arrived at our current methods of transportation, how we have improved upon an original concept, and continue to improve. We achieve the same results with technology, and our continual improvements.

Alternative transportation methods are innovative ways we have modified this original concept to incorporate advanced technology to benefit our community and make transportation easier.

Alternative transportation may refer to bicycles, eScooters and mopeds, as well as more advanced options such as autonomous vehicles (AV) and automated transit services.

Although these transportation modes are not necessarily new, the examples used here demonstrate how the fundamental concepts have been modified to provide an easier way to move from A to B.

6.1 Bicycles and eScooters

Bicycle infrastructure in North America, particularly in the north-west of the USA and Vancouver in Canada, is well established. During the tour, we utilised the established Bike Share options: Mobi bikes in Vancouver and the Biketown service in Portland, Oregon. The two services operate with a number of fundamental similarities. They each have their own app, which is simple to use. The bikes are docked at docking stations, and there are several options for payment, through a subscription (such as monthly or yearly), or a pay as you go option. To complete your journey, the bikes must be securely docked or the user continues to be charged usage fees.

Figure 4 – eScooter & bicycle docking - Portland

The docking stations securely store the bikes. There are docking stations located at many convenient locations throughout the cities and suburbs, and these can be located through the app, allowing the user the ease of locating the nearest docking station. This simple system is highly effective.

Figure 5 – The under-utilised Melbourne Bike Share

In comparison, the Melbourne Bike Share program was implemented without adequate bike infrastructure available, and had issues surrounding the strict and enforced Victorian helmet laws, as well as the free tram zone within the CBD. As a result, it failed and was scrapped by the Victorian Government in 2019.

There has been much debate surrounding the helmet laws in Victoria and how this may have contributed to the program's failure. The state government eventually began subsidising the sale of helmets from local convenience stores for $5 in an attempt to encourage higher usage. Helmets were at one point provided free

with the bikes, but hygiene concerns continued to discourage potential users. The helmet requirement placed a barrier on casual users and tourists.

The scheme was rolled out on a relatively small scale compared to that in other cities such as Vancouver or Portland. While the idea of starting small before expanding to a wider area and providing more infrastructure may be a smart one, it meant that very little options were available around the inner suburbs, making the usage of the bikes difficult outside of the CBD. The Melbourne CBD has almost no dedicated bicycle infrastructure, discouraging bicycle travel.

Elizabeth Kim, General Manager of Mobility at the RACV is quoted as stating:

> *"Helmets might have been one of [the contributing factors to the failure], but really, the free tram zone, being able to get on a tram right next door to the bike share stations [discouraged use]. Also, at the end of the day the bike share scheme was quite small for a city of this size"*

Another company, oBike, a Singapore-based company, attempted to roll out a dockless bike sharing program in Melbourne several years ago. This program was a quick failure, with many of the bikes being dumped in inaccessible and obscure locations, vandalised, and many ending up in the Yarra River. The bikes were removed from the streets of Melbourne within a year.

Figure 6 – oBike

Bicycle infrastructure in Melbourne is often regarded as poor. Cyclists are generally required to use the same roadway as vehicles, and negotiate challenges such as parked vehicles, congestion, trams and buses, and pedestrians.

Coupled with this is a cultural intolerance to cyclists on roadways. There is ongoing debate regarding the use of the existing road by cyclists and whether cyclists should be paying an additional registration fee for their bicycles to utilise the road network, despite the fact that the majority of cyclists hold a valid driver's license.

Melbourne has developed a good network of off-road trails, which prove popular, and link between each other forming a complex network of trails. Many of these are fantastic recreational trails, but lack the connectivity for many to utilise the network to commute. New major State-funded road projects typically now require a shared path be constructed along the full length of a project in and around Melbourne. This fantastic initiative is contributing to a wider

and more accessible network of safe off-road trails which can be utilised by commuters, and families alike.

Although bicycle use as a means of transportation has significantly increased in Melbourne (See **Figure 7**), the above factors frequently contribute to a hazardous cycling environment that causes a level of concern and is a barrier that may prevent many from commuting via this means of transportation. Instead, commuters generally opt to drive or utilise the public transportation system – also regarded as relatively poor in Melbourne.

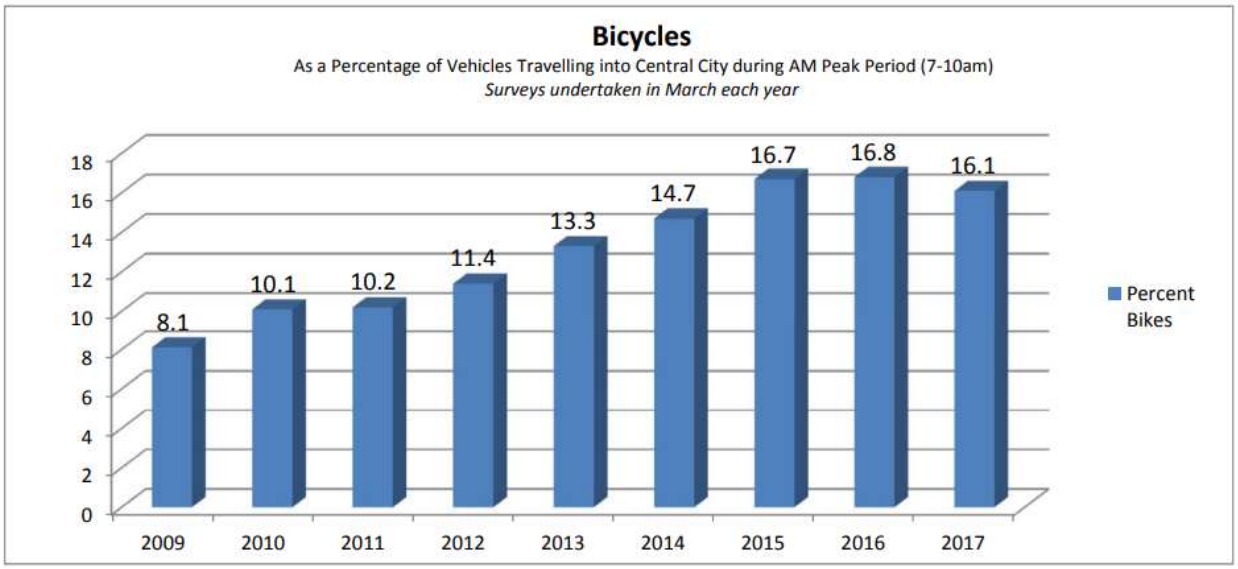


Figure 7 – Increasing Bicycle usage. City of Melbourne

Studies from around the world have continued to demonstrate that improved bicycle infrastructure leads to increased usage, particularly in parts of Europe where bicycle commuting is ingrained in the culture.

All cities visited by the study tour team had their own bike share program of some sort. The team utilised the bike share service in both Vancouver and Portland, using the service to undertake tours of the city's bicycle infrastructure and extensive bicycle network. Although each system operates differently, has a different fee and payment structure, and different hire methods, they are all simple to use and utilise the user's mobile phone to some degree.

Mobi launched in the summer of 2016, and continues to receive high usage data throughout Vancouver. Although a relatively young bike share network when compared to other cities around the world, it is one of the most effective. The City of Vancouver provide detailed cycling

maps, showing both on-road and off-road paths, allowing the user the option to select a safer route to their destination. The maps detail connectivity in and around the Vancouver Downtown area, as well as the surrounding suburbs and attractions. The map shows the AAA network, the All-ages and abilities bike path network, and its connectivity. The AAA network is a brilliant asset to Vancouver, and heavily utilised by the public. This map can be viewed in the Appendix.

Bicycle infrastructure in Portland was similarly advanced, with the investment in the Tilikum Crossing commuter bridge over the Willamette River, one of many bridges over the river, but the first to restrict usage to public transport, and pedestrians and bicycles only. This is further expanded upon in section 6.2.4.

With the comparison to bicycles in Melbourne, there is far greater community acceptance of bicycle usage across the United States. Greater implementation of bicycle infrastructure including bicycle trails and on-road bicycle facilities would greatly increase community acceptance across Melbourne, improve safety and reduce the conflict associated with bicycles utilising the existing road network. Patronage would increase, and the intolerant members of the community may even become cyclists themselves.

Most cities visited by the team had an eScooter program in addition to their bike share program. eScooters are electric scooters, fundamentally operating in the same way as bike share programs.

The scooters do not have docking stations and rely on the user to place the scooter at one of the many designated parking locations.

They offer a simple and effective way for users to travel short distances through cities. They are popular amongst locals and tourists alike. Unlike bikes, the user does not need to physically exert themselves. In a way similar to bike share, the user locates the nearest eScooter through an app, and in turn uses the app to activate and use the eScooter.

eScooters do not have dedicated infrastructure associated with them, and as such must utilise existing infrastructure such as bike paths and sidewalks. This can create a risk associated with collision with pedestrians or cyclists. The eScooters are low speed, and limited by distance due to battery capacity.

They are generally accepted as a viable means of transport in the cities we visited. We did not notice eScooters inappropriately stored or dumped. The vast majority were parked in either

designated locations, or locations central and easily accessible, but out of the way and not impeding pedestrian movement around the cities.

6.2 Autonomous Vehicles

Autonomous vehicles have a longer history than many people would be aware. The desire for automation goes back as far as 1478 AD when Leonardo da Vinci invented his self-propelled cart, powered by two symmetric springs under high tension. This machine, considered the ancestor to the modern automobile, used an internal balance wheel. The balance wheel, which is similar to that used in clocks, prevents the rapid drop in spring force enabling the delivery of smooth and stable motion. Steering could be set in advance, allowing the cart to move on a predetermined path. This combination provided a small cart, which would track along a pre-determined path at a consistent pace. It was designed as a special attraction for visitors at the Renaissance Festivals with intention to instil wonder and awe in attendees. It is sometimes considered as the world's first robot and has provided inspiration for generations.

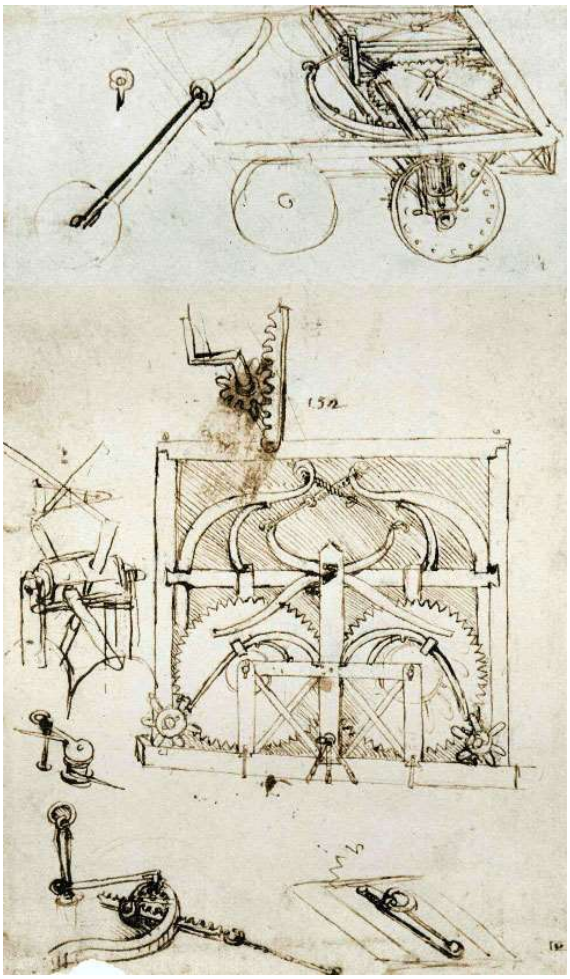


Figure 8 – Original design for da Vinci's self-propelled cart

Other innovations through history further inspired the desire to fully automate. The Whitehead Torpedo (1868), Mechanical Mike aircraft autopilot (1933), Teetor Cruise Control (1945), Stanford Cart (1961), and VaMoRs (1987) are just some of the critical steps through history towards automation. One of the most recent and notable advances is the Tesla Autopilot of 2015, giving way to the belief that we can have self-driving vehicles in the near future.

A presentation at PWX in Seattle by Sam Yaghmaie, project manager at Kennedy Jenks, a large US-based civil engineering firm, discussed the commencement of the race towards fully autonomous vehicles. In 2004 (only 15 years prior to the presentation presented at PWX), a

Figure 9 – The Stanford University winning vehicle

robot car race was held in the Mojave Desert in California. Known as the DARPA Grand Challenge (DARPA: Defense Advanced Research Projects Agency), the challenge offered a grand prize of $1 million to the winner and was open to international competitors. The intent was for competitors to develop a fully autonomous vehicle capable of travelling the 240km course through the Mojave Desert unassisted. In the first ever race, all competitors failed to finish, and a grand prize was therefore not awarded, being deferred to the following challenge twelve months later, and raising the prize money to $2 million. Although during the 2004 event, the vehicle managing to travel the farthest distance failed after becoming stuck on rocks at only 11.78km, the race the following year in 2005 brought with it significant advancements in research and design by competitors, and as such the race was won by the Stanford University Racing Team with a time of six hours and 54 minutes. In stark contrast to the previous year's competition, all but one of the 23 competitors surpassed the distance managed by the best competing vehicle in 2004, with five competitors successfully completing the course. The course was revised in 2005, with a total distance of 212km.

The advancement over the last five to ten years, particularly in relation to sensors and computing technology, means that vehicles now have the ability to operate motor vehicle functions without the input of the driver. The Society of Automotive Engineers (SAE) defines 6 levels of driving automation ranging from 0 (zero automation) to 5 (full automation). The US Department of Transportation has adopted these levels. **Figure 10** on the following page from the SAE illustrates the six different levels of driving automation.

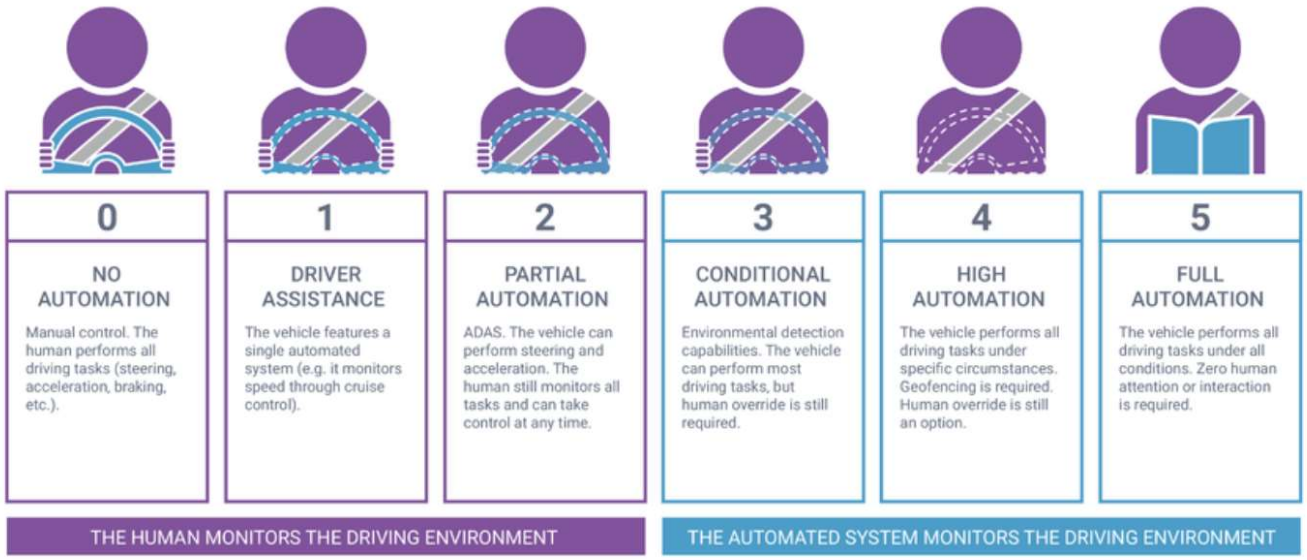


Figure 10 – Levels of Driving Automation – The Society of Automotive Engineers (SAE)

Many new vehicles available on the market come with Level 3 automation. These common vehicles, many of which can be seen on our roads, have an array of cameras and sensors, inbuilt GPS, radars and more. They use a combination of these features to assist the vehicle user by operating certain functions of the vehicle.

For example, engaging cruise control in many modern vehicles fitted with this technology, particularly on a city freeway, uses radar and other sensor technology to maintain a safe breaking distance from the vehicle in front. It will slow down, break and accelerate on behalf of the driver, increasing the safety and assisting in the prevention of rear-end accidents. In addition, lane centering technology assists in keeping the vehicle within the centre of the lane, and prevents the vehicle from veering into other lanes or from the road completely.

Theoretically, these vehicles can be driven fully autonomously while cruise control is engaged, without the need for the driver to utilise the brake or accelerator pedals, or the steering wheel. Added safety features however prevent the driver from letting go of the steering wheel, ensuring the driver remains alert and in control of the vehicle and maintaining these vehicles within the automation Level 3.

According to researchers at ABI Research (A link to this research paper can be found in the bibliography), we could see approximately 8 million autonomous or semi-autonomous vehicles on the road by 2025. With so many new vehicles incorporating automated features, it is not hard to imagine this figure becoming a reality. The below **Figure 11** from the SAE demonstrates in further detail the levels of automation and what they mean exactly in terms of vehicle functions and features.

LEVELS OF AUTOMATION	WHO DOES WHAT, WHEN
Level 0	The human driver does all the driving.
Level 1	An advanced driver assistance system (ADAS) on the vehicle can sometimes assist the human driver with either steering or braking/accelerating, but not both simultaneously.
Level 2	An advanced driver assistance system (ADAS) on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances. The human driver must continue to pay full attention ("monitor the driving environment") at all times and perform the rest of the driving task.
Level 3	An Automated Driving System (ADS) on the vehicle can itself perform all aspects of the driving task under some circumstances. In those circumstances, the human driver must be ready to take back control at any time when the ADS requests the human driver to do so. In all other circumstances, the human driver performs the driving task.
Level 4	An Automated Driving System (ADS) on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. The human need not pay attention in those circumstances.
Level 5	An Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving.

Figure 11 – What do the Levels of Driving Automation mean? – The Society of Automotive Engineers (SAE)

Sam Yaghmaie stated in his presentation that one million AV's will generate over three billion people's worth of data, an extraordinary figure.

Trials of Level 4 and 5 automation continue around the world with the race for full automation. Autonomy is not limited to motor vehicles alone. Many cities the group visited through the study tour had fully or partially autonomous trains to assist people travelling to the Downtown area of the cities from the airport, as well as between airport terminals. An example of this was the Vancouver Airport Skytrain, the rapid transit train connecting YVR (Vancouver International Airport) with Downtown Vancouver. The train alternates between an above-ground 'skytrain',

and a tunnel, and operates as a semi-autonomous train, stopping at several suburban stations along the way.

Both Seattle-Tecoma Airport (SEATAC) and Denver International Airport (DIA or DEN) operate fully autonomous shuttle trains between terminals. This is due to the size of the airports, and the airport layout. The underground shuttles connect the terminals, allowing terminals to be separated and a more simplistic layout developed. DIA is America's newest major airport, opened in 1995. It is also the largest by area in North America, and the second largest in the world, while it is fifth busiest in North America. The airport was moved from its central location near the Downtown Denver area. The former site has since been developed as a retail and residential neighbourhood. The design and construction of the new airport allowed a smart new design incorporating separated terminals and an automated terminal connection system called the Denver International Airport Automated Guideway Transit System. This transit system is fully autonomous and runs every few minutes.

Similarly, the system at SEATAC is fully autonomous. Known as the Satellite Transit System (STS), it is an Automated People Mover (APM) system. It opened in 1973 – the second oldest airport people mover system in the United States.

Figure 12 – Autonomous Train – Vancouver

Figure 13 – Autonomous Train – Seattle Airport

The City of SeaTac, which includes the area around the SeaTac Airport, located about midway between the City of Seattle and the City of Tacoma, passed a resolution in September, 2018 declaring support and its interest in maintaining a municipal leadership role in support of autonomous vehicles. The City has been developing an action plan for development and deployment of autonomous cars, trucks and buses on its roads.

With the invention and implementation of 5G around the world, AV technology is harnessing this advancement and really taking off. Up until recent times, 4G technology hasn't been fast enough. In 2019, 5G has the ability to process data at a rate 100 times faster than 4G, really opening the door for the advancement of AV, associated AI and additional technology.

Technology is improving through all aspects. Batteries are becoming cheaper and more efficient, and with the improvement in battery technology, comes longer lasting and faster charging vehicles.

Sam Yaghmaie spoke in his presentation at PWX about the wireless charging of AV through magnetic resonance. A potential for significant improvement into the future could see our city streets transformed, with basic magnetic fields installed under the road surface connecting to the existing power service, allowing AV to wirelessly charge as they drive through the streets. This technology is already readily available and used to charge mobile phones through wireless charging devices, and it is said that in the future, users will be able to place their device on a café or coffee shop table or desk for a quick recharge while the device remains on the charging platform.

6.2.1 City of Boston

The City of Boston is a highly progressive and innovative City. The engineering team, led by the influential Chris Osgood, Chief of the Streets, Transportation & Sanitation are provided with the freedom and inspiration to innovate within their day-to-day operations. Chris's belief that he needs to allow space for creativity is an important aspect of his leadership. Providing staff with the space to create and innovate, to take risks and to occasionally fail, while maintaining the support he provides, creates an enormously efficient and positive team. This demonstrated firsthand the importance of leadership in championing and supporting staff to build a positive culture. It was clearly evident on our visit to the City of Boston, how much the staff respect and trust their leader, and the impact that had on the organisation. Having the right skill mix, and encouraging innovation as part of their normal responsibilities, while providing significant support and encouragement allows staff the freedom and capacity to bring those ideas forward, and provides the space for innovation.

Figure 14 – Chris Osgood

The City of Boston currently has two autonomous vehicle companies testing autonomous vehicles within the city:

- Autonomous Prime
- nuTonomy

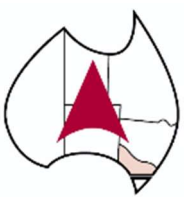
The trial area is located within the Seaport District – an area around the docks with generally lighter traffic and minimal pedestrian movements. The trial is only operational when a set of strict conditions are met. Martin Walsh, City of Boston Mayor said in a statement:

> *"Continuing to test autonomous vehicles in a careful and methodical manner represents another step forward in helping us to achieve the vision for improved mobility that was established by residents during the Go Boston 2030 Transportation Plan public process. If deployed thoughtfully, shared fleets of autonomous vehicles could offer the city of Boston the potential to improve safety on our streets, provide equitable connections to the MBTA (Massachusetts Bay Transportation Authority) and offer a new source of mobility to all Boston residents."*

The City of Boston recognises the importance of this trial, and have been considering the important things for the City and how this may impact mobility. They recognise the need to get the policy right which they were working on at the time of our visit. A note from the team during our visit that is worthy of publishing is an important reminder of the direction they intend to take autonomous vehicles:

> *“Utilising autonomous vehicles to assist with public transit – the world gets better. Using autonomous vehicles to replace personal vehicles – the world gets worse.”*

Through our discussions with the team at the City of Boston, they acknowledged some of the challenges the team are currently working on. One of these challenges is the need to develop a large database to record planned and unplanned road closures which may be due to planned or emergency works, vehicle or other accidents, movie filming and more. These considerations are uniform across the world and should be considered when introducing the technology to streets in our own municipalities.



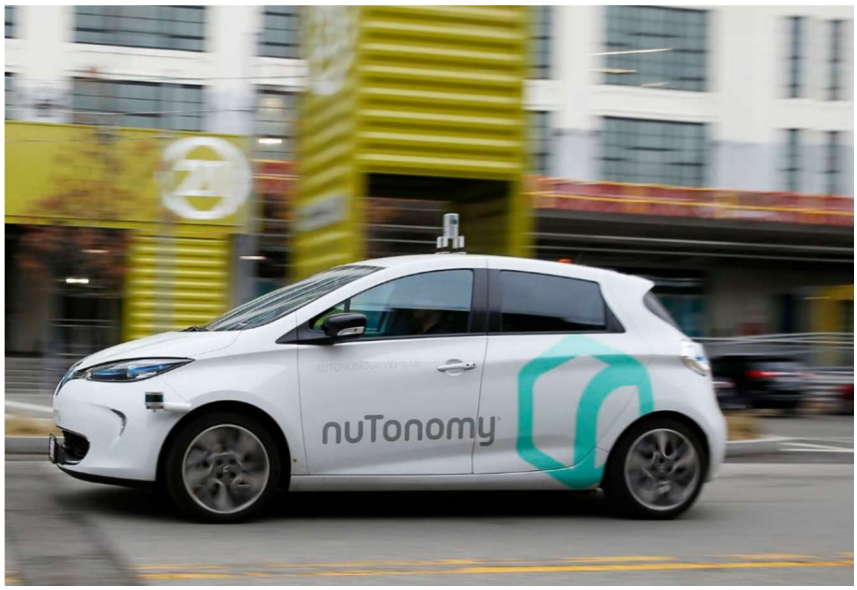


Figure 15 – nuTonomy vehicle in the Seaport District.
Photo: The Boston Globe

They raised the point about ensuring pavement markings and signage are correct and up to date, ensuring they are well maintained, and asset management records are strong. Having said this, the discussion led to confirmation that pavement markings are not critical in terms of AV. AV technology has improved to the extent that pavement markings are no longer a critical component, although it does assist.

The point was also raised that AV does not need advanced Internet of Things (IoT) technology or signals at this point. It is best to keep things simple at this early stage.

One of their current failures is kerbside management, and in particular, parking spaces. The City is currently unaware of how many parking spaces it has available, and this could prove key for AV technology. For example, the number and type of parking spaces in front of City Hall is currently unknown. Technology such as parking sensors may need to be rolled out across key locations, linked back to the database to ensure AV is aware of available spaces, and is able to determine the best and safest locations to drop off users and park.

As the City of Boston continues to learn and develop its policies and infrastructure, AV companies continue to develop their technology and undertake trials through city streets.

Figure 16 – The Boston City Hall – a unique design

6.2.2 Colorado – Panasonic CityNOW & NREL, Denver, CO

Panasonic CityNOW is located within the Peña Station NEXT precinct in Denver, Colorado. Peña Station is a new community, developed around the existing Peña Train Station – the first train station towards Denver Downtown from Denver International Airport. It is a new community, still under development, combining an integrated and connected

Figure 17 – Panasonic CityNOW building with Easy Mile office

Figure 18 – Panasonic CityNOW control room showcasing live Smart City innovation data

community, smart grid clean energy and enhanced mobility. In short, it is a community designed entirely around Smart City principals and innovation. It is setting a new standard for smart, sustainable, connected living.

Panasonic CityNOW is the “Smart City of tomorrow”. The factory is enormous and stands at the centre to the Smart City precinct of Peña Station.

Within the factory, an office for Easy Mile exists. Easy Mile is a driverless tech company based in France. The company is approximately five years old, demonstrating the young age of this technology. Until very recently, the Peña Station precinct has been host to a driverless shuttle, a 15 seat electric shuttle running around the precinct amongst existing (low level) traffic and pedestrian movements. It has proven to be a highly successful operation and allowed the company to further improve the design of their shuttles. The driverless shuttle now operates

around the NREL (National Renewable Energy Laboratory) campus in Golden, Colorado. More information regarding NREL can be found in Chapter 9.

Figure 19 – Easy Mile shuttle outside Panasonic CityNOW. Photo: The Denver Post

The company has manufactured 120 shuttles, and currently have approximately 30 projects in the United States. The shuttles are designed specifically for university campuses, and other similar campuses such as schools and hospitals. They are designed for a low speed environment and are currently sitting at a Level 4 driving automation level.

Easy Mile have a new initiative in the planning stage – Tracked Easy. This arm of the business will be specifically designed for freight and goods transfer up to 25 tons.

All testing of AV's by Easy Mile (and to the group's knowledge, anywhere else, and by anyone else in the US) has been completed up to and including Level 4. This generally means that the vehicle has a safety officer on board to ensure that the vehicle travels safely and no errors are made. Easy Mile has commenced its first ever Level 5 trial – a fully autonomous vehicle travelling around a university campus in France without a safety officer. This vehicle is supervised remotely – from an office four hours away. The trial is still in its infancy, but is showing promising results.

Easy Mile aims to ensure their vehicles are talking to each other, and not necessarily to the infrastructure. As this occurs, we will be able to get the vehicles talking to each other, as well as reading and understanding the infrastructure.

The Easy Mile autonomous shuttle undertook a six month trial within the Peña Station precinct, transferring the shuttle to the NREL campus in Golden starting on 9 September 2019, not long before we arrived in Colorado. The shuttle was based at the large research facility at the time of visiting and transports NREL employees around the campus, while NREL continue to test the autonomous technology in conjunction with Easy Mile. In addition, it is a unique opportunity to also test and study the employees' reaction to travelling in an AV, particularly noting the use of one without a driver (but with a safety officer on board), while also monitoring employees' reaction having an AV travelling around the campus and utilising the existing roads and paths within the campus.

Figure 20 – Signage at NREL

Figure 21 – Autonomous shuttle at NREL, Golden, CO

The shuttles incorporate a complex array of cameras and sensors including radar and LiDAR, GPS, video and infrared cameras, ultrasonic sensors and more. The vehicle technology collects the information using this combination of sensor and camera technology and analyses the information immediately, processing the data and making appropriate decisions based on safety, road rules and logic. The image to the left illustrates the many cameras and sensors incorporated into the Easy Mile shuttles while being utilised during winter at Peña Station. These can be seen at the corners of the vehicle, on the roof, and within the front and sides of the vehicle. Winter in Colorado creates another difficulty with the need to operate through snow. A level of artificial intelligence (AI) is incorporated into the vehicles to ensure learning and standardisation across the fleet. AI is an important aspect of AV technology and another industry separately developing and growing its technology.

6.2.3 Portland Aerial Tram

The Portland Aerial Tram is a wonder in alternative transportation. Owned by the City of Portland and operated by the Oregon Health & Science University (OHSU), the aerial tram is effectively a large gondola, connecting the South Waterfront District to OHSU and the Marquam Hill District Park. The university operates a fully functional hospital, and "is where healing, teaching and discovery come together" according to their website. It is effectively a hospital and a university, wrapped into one package. The hospital services are considerably diverse.

The tram rises 500 feet (150m) above the ground, and travels 3,300 feet (1km) between the two stops. A smart development, and one which encourages commuting by bicycle is the Go By Bike facility. An enormous storage area for bikes, encourages staff and students at OHSU to commute by bicycle, securely store their bicycle at the Go By Bike facility, and travel via the aerial tram to the Marquam Hill Upper Tram Terminal, in the heart of OHSU. The aerial tram is one of the only aerial commuter trams in the country and runs year round. The tram is ADA-compliant, and welcomes mobility-assisted devices. It is an approximate four minute trip, and is designed as standing room only, however there are four seats for those that require a seat. The trams have a 79 person capacity and travel at 22 miles per hour (35km/hr).

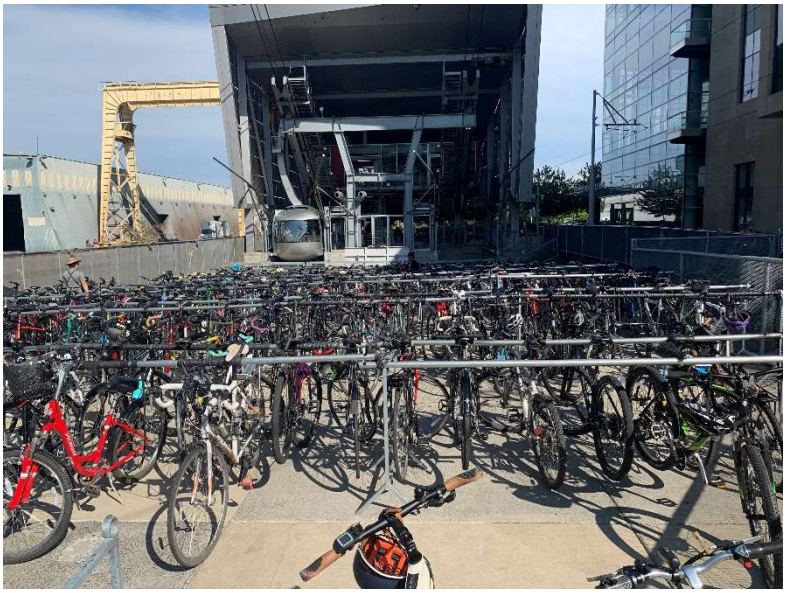


Figure 22 – Significant bike storage at the Waterfront tram terminal

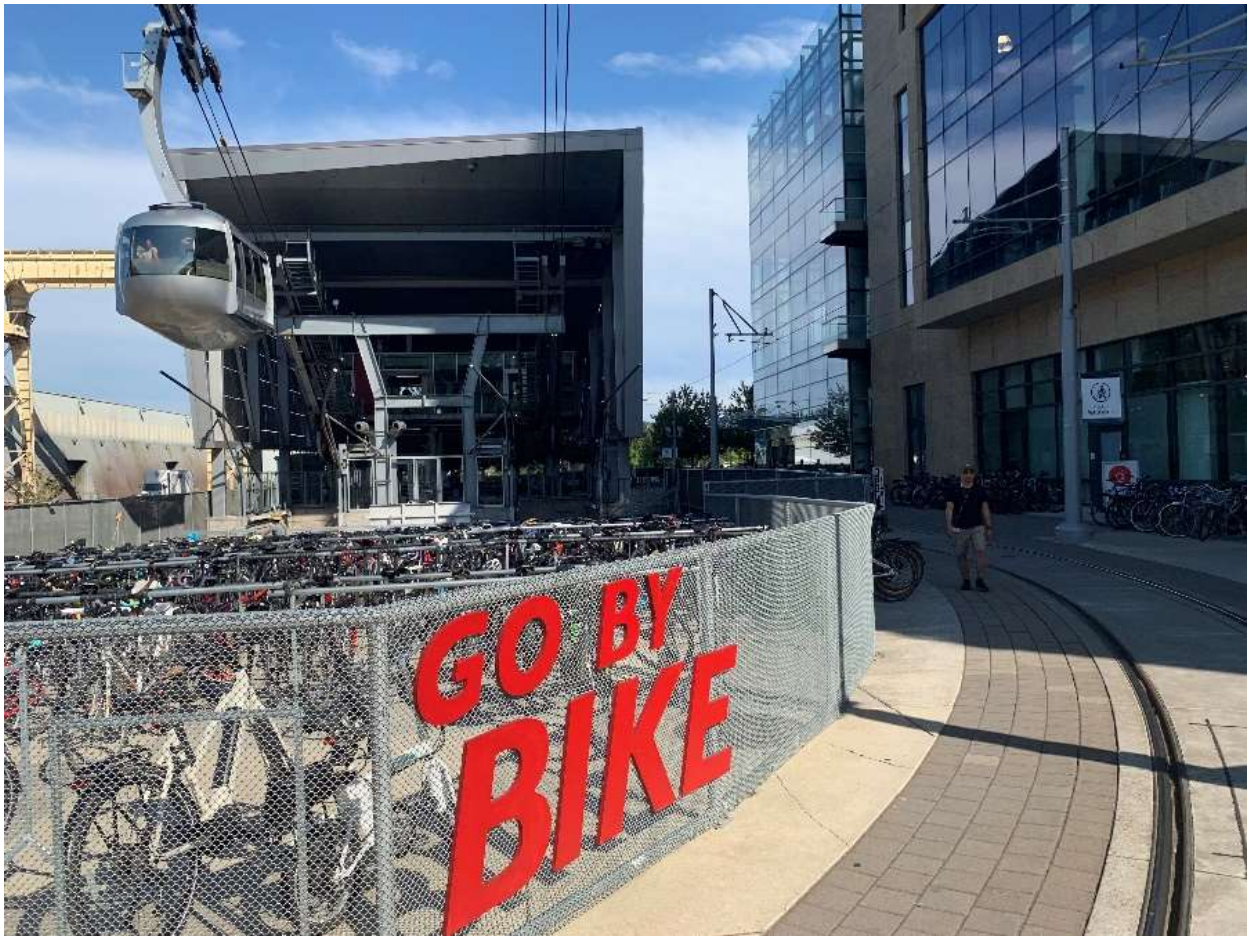


Figure 23 – The Go By Bike facility, including aerial tram

OHSU badge carriers (staff) are permitted to use their badge as eligible complimentary fare. The tram is primarily set up for staff and visitors to access OHSU, however tourism numbers have increased dramatically in recent years. OHSU receives up to 20,000 visitors a day, and is Portland's largest employer and medical destination, as well as being home to several medical schools. With only two roads to this destination, which includes a residential neighbourhood, and nature trails, an ambitious and innovative solution was required. A fantastic solution for the people of Portland, the Portland Aerial Tram was funded by OHSU ($40 million) and the City of Portland ($8.5 million).

6.2.4 Tilikum Crossing Bridge, Portland, OR

Figure 24 – Tilikum Crossing, Portland, OR

Near the base of the Portland Aerial Tram, and conveniently linking with the tram is the Tilikum Crossing, a new bridge opened in 2005 crossing the Willamette River. The Tilikum Crossing Bridge is known as the Bridge of the People, due to its original intent. It was built for the light rail passenger trains, streetcar, and buses, as well as pedestrians and cyclists, and emergency services. Private vehicles or trucks are not permitted to cross the bridge. It is the first bridge in the United States to be designed with such restrictions.

The City of Portland is sometimes known as the City of Bridges, due to the immense number of bridges over the rivers, and in particular, noting the architectural brilliance of the majority of these bridges. The Tilikum Crossing Bridge however is the first new bridge to be opened across the Willamette River in the Portland area in almost 50 years.

The new bridge is a fantastic addition to the city, and provides great encouragement for pedestrian and bicycle usage, ultimately increasing alternate means of transport. Preventing cars and trucks from using the bridge increases the comfort and safety for users, particularly those on foot and bicycles.

7. Smart Cities & Innovation

What does the term “Smart Cities” mean? Techopedia defines a Smart City as the following:

> *“A smart city is a designation given to a city that incorporates information and communication technologies (ICT) to enhance the quality and performance of urban services such as energy, transportation and utilities in order to reduce resource consumption, wastage and overall costs. The overarching aim of a smart city is to enhance the quality of living for its citizens through smart technology.”*

There are many definitions across the Web and through the industry. There is no universally accepted definition as it can mean different things to different people and/or organisations. Smart Cities vary greatly across the world, and largely depend on the level of deployment, willingness to change, resources, and aspirations of the governing body and the residents.

So what does this mean in plain English?

It can be said simply that a Smart City is a city (or town, or municipality, etc) that applies digital technology, data and innovative practices to improve liveability, sustainability and productivity.

Within Smart Cities, innovation goes hand-in-hand. Innovation is incredibly important – if we are to succeed in local government, we need to innovate regularly and empower our staff to pursue creative and innovative options, maintaining the organisation’s standing at the forefront of the industry. We at Manningham see this as incredibly important and maintain this approach through our organisation as best as practical.

Figure 25 – Smart sensors at Peña Station

The City of Columbus, Ohio recently won the Smart Cities Challenge, a $50 million challenge for funding based on the ideas and information submitted by the competing

municipalities. The City of Columbus aims to improve people's quality of life, drive growth in the economy, foster sustainability and more through implementation of its smart city plan.

7.1 Smart Infrastructure

Smart Infrastructure can be defined as any infrastructure associated with the Smart City goal. It is the nuts and bolts, the physical components of the system. It generally refers to the sensors, cameras and other technology collecting the data and feeding it back to the systems or operating system. The operating system can be on site (autonomous vehicles are a good example of this), or elsewhere in an office or a data centre.

7.1.1 Smart Infrastructure

Smart Infrastructure can refer to many different types of sensors, cameras, or other infrastructure, utilised to collect data and information for analysis behind the scenes, and eventual interpretation and presentation of the findings.

Peña Station, east of Denver in Colorado is a great example of a new development incorporating smart infrastructure. At this site, a multitude of sensors and other collection infrastructure have been incorporated into the development, where it is transferred to the Panasonic factory, interpreted and later presented.

This development is a leader in innovation and technology, and has incorporated as many sensors and environmentally sustainable features as possible. Sensors and cameras can be seen throughout the street network, as well as on buildings and in and around the large commuter carpark next to the train station.

These sensors measure various things including the weather and atmospheric conditions, traffic and pedestrian activity, condition information for assets, and many other things.

Other smart infrastructure may include that found on AV such as radar and LiDAR among many other cameras and technology. Similarly, sensors found in road pavements to measure data such as traffic volume and impact may asset in managing assets efficiently into the future.

7.1.2 Data and the back-end

Data is the information collected by the infrastructure designed to collect the appropriate data for processing, analysis and interpretation. In terms of AV, which is much more sophisticated,

the data is collected, analysed and interpreted in microseconds, and a decision made through AI which in turn dictates the functions and movements of the vehicle immediately.

Smart city data collected through infrastructure such as roads is often collected and added to a database, where it can be analysed and interpreted at a later stage by the operator of the system.

Manningham Council's Smart Cities project is a good example of this and is described in detail in **Chapter 7.1.5**. Through this project, data is collected from the vehicle sensors underneath parking spaces, and the atmospheric sensors located strategically throughout the shopping precinct which was the subject of the project.

7.1.3 Why pursue a "Smart City"

According to a United Nations study in 2008, cities consume between 60 and 80 percent of energy worldwide, and are responsible for large shares of emissions. Although this contributes to a strong economic performance, it also contributes towards poor environmental performance.

In addition to this, the lower the urban density, the more energy is consumed for electricity and transportation, proven by the fact that carbon dioxide (CO_2) emissions per capita drop with the increase in urban density. This was demonstrated in a study published in 2011 titled Cities & Green Growth: A Conceptual Framework. A link to this study is provided in the bibliography.

As the world changes, and becomes more urbanised, more and more people are choosing to live in cities. According to the United Nations Population Fund (2008), 2008 was the point in history where we surpassed 50 percent of all people in the world, approximately 3.3 billion at the time, living in urban areas. This figure is expected to rise to 70 percent by 2050, an enormous shift from the 2008 figure.

Cities are enormous consumers of goods and resources, with mostly waste as the output. The nature of a city means that it relies heavily on external resources. Sustainable solutions have been at the forefront of thinking and design for many years now, however with the increasing city populations, coupled with the above facts, cities around the world have been moving towards a smarter way of managing their infrastructure. Taking

Figure 26 – The City of Portland are at the forefront of innovation

the local government example, municipalities in Victoria are being forced to find ways to manage new challenges, of which I could list many, including rate capping, and the previously mentioned challenges. Municipalities in Victoria are now needing to follow the lead of major cities around the world and start looking for solutions to these challenges.

The concept of “Smart Cities” however is not confined to the application of technology in cities. As mentioned earlier, there is no simple definition for Smart Cities or a smart city, and as such, the term has generally been collectively used to refer to the ‘smart’ technology and infrastructure being utilised by a city, municipality, or other authority/organisation to improve the sustainability, liveability and productivity of that body through the use of technology, data and innovative practices.

7.1.4 Failures & Learnings

While meeting with many organisations, we learnt of many trials and attempts at smart city infrastructure, some of which had failed. The team obtained great information and found it very interesting to learn about the failure side of Smart City infrastructure. Discussing failures, and how some of the challenges may have been overcome was beneficial to all three of us, while learning from what didn’t work has improved our overall understanding. A number of organisations were brave enough to share their failures with us, and were very honest in doing so. We thank them for having the courage to share these details with us.

7.1.4.1 City of Portland, OR

We were fortunate enough to meet with the City of Portland’s Bureau of Transportation (PBoT). PBoT have an incredible team, and lead the way through innovation. Led by the impressive Steve Townsend, City Engineer, the team thrive in innovation and alternative transportation.

The City of Portland is broken into bureaus, like many US cities, with PBoT effectively one of the ‘departments’. PBoT is funded through parking revenue and the city’s gas tax. US municipalities are free to set their own local tax at gas stations within their municipalities as a means to raise rates and revenue. Voters within the City of Portland passed a ten cent per gallon gas tax which is applied within the municipality, one of the highest gas tax rates in the country. Business tax and property tax is primarily used to fund the police, fire and parks bureaus.

PBoT has been focusing on alternative modes of transportation to move people around. The City of Portland has exploded in population since 2015, and with this population explosion

comes congestion with additional vehicles, and drivers not normally familiar with the Portland driving 'culture'. This is evident through driver behaviour. Portland has always been a bike friendly city, and had a strong cycling culture, with cycling being a popular mode of transportation.

Careful consideration must be given to declining income if vehicle numbers through the city are to be reduced. Given the bureau is funded through gas tax and parking revenue, a reduction in vehicles through the city would result in a reduction in funding available for the department. This was one of the considerations given to the high gas tax, and marketed correctly, the voters passed it.

PBoT have been focusing on how to incentivise people to use public transport through experimenting with bus passes and other innovative options. They have their own smart cities team focusing on the implementation of smart city infrastructure.

The team installed an array of traffic safety sensors through a safety pilot. The bureau was about twelve months into the pilot at the time of meeting, and had many preliminary results and findings they were able to share. The sensors are mounted to existing street lighting mast arms through the specially designed mounting bracket.

Figure 27 – Traffic safety sensors

Clever marketing, and the vendor effectively withholding important information meant that the City adopted something that was not entirely reading to be deployed. A strong learning from this process that PBoT were able to take away was not to believe the vendor's claims, and to undertake their own thorough research. The City was unaware that they were effectively deploying an unfinished technology, one which had not yet undergone rigorous testing, and as such, renegotiated the contract with the vendor. They receive eighteen months of free data which was negotiated when implemented – this now commences when the units start working properly.

The sensors have enormous capabilities, however most of the capabilities have been switched off to appease resident's concerns, and ensure they don't receive any privacy complaints for the duration of the trial project. The sensors include but are not limited to the following capabilities, most of which have been switched off by PBoT:

- Detect gun shots
- Video & microphone capabilities
- Bluetooth and Wi-Fi tracking
- Facial recognition
- License plate tracking

Given most of the above capabilities have been disabled, the sensors are effectively being utilised to collect traffic and pedestrian data, effectively becoming glorified traffic counters.

Figure 28 – The team with Steve Townsend – City Engineer, PBoT

The sensors have been able to provide good data in return, but have also proven to come with some inconsistencies and issues. It became apparent through testing that the sensors were unable to identify the differences between some objects. For example, the sensors were unable to differentiate between a cyclist riding a bike, or a bicycle being transported by a vehicle, or on the front of a bus. All buses have bike racks located on the front in Portland, and they are generally well utilised and often full, so this has the potential to throw the data out significantly. It was determined that the technology was able to detect bicycles, but not cyclists. An inaccurate collection of data with many variables. What if a pedestrian is walking a bike along the sidewalk?

The sensors transfer data to the City database, and auto rewrite within the sensors after seven days. The sensors carry an on-board computer with many capabilities and as mentioned, not all are utilised. PBoT owns the units outright, which cost approximately $5,000 per unit. PBoT allocated $1 million towards the safety pilot, with 200 sensors installed within a small part of the city, mostly within a commercial area. PBoT has determined that 200 sensors is far too many for the area, but the ultimate number of sensors is unknown at this point in time as the trial is ongoing. 40 of the sensors were not working at the time of meeting, with no money allocated to

maintain the sensors. They have proven very expensive to maintain as each time maintenance is required, traffic management and specialist contractors are required. The sensors are approaching the 50% failure rate.

Interestingly, given the capabilities of the sensors, the FBI (Federal Bureau of Investigation) is interested in potential collaboration and utilisation of the sensors, and in particular, the facial recognition and license plate recognition technology. PBoT however, has committed to focus on one thing at this point in time and separate the final outcomes. Once the city is satisfied with the successful operation of the sensors, they may consider the possibility of potential collaboration following a rigorous public consultation process.

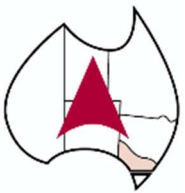
It was noted during our visit that the City of Seattle has recently made the mistake of installing similar units and not adequately consulting with the public, resulting in public concern/backlash. As a result, a community-based committee was established to approve or deny any innovation ideas within the public realm, not a good outcome. This could prove to be problematic and potentially act as a blocker to any future Smart City initiatives within the City.

PBoT are currently working quite hard to sell these (and other) ideas and innovations to the public and develop a credible reputation. They discussed with us the importance of getting the public onside with these types of innovations. They don't want the public to be risk adverse, they will never be prepared to try anything innovative again if this is the case.

The team described the process with a fantastic quote:

> *"We have to fly the plane while building it"*

A very good representation of the process so far. Overall, and in the words of PBoT staff, the experience to date has really set a level of learning and experience for the city, creating an excellent base for future innovation.



7.1.4.2 City of Elmhurst, IL

Figure 29 – The team was greeted with the water mascot on arrival at the City of Elmhurst

The City of Elmhurst, a fairly wealthy area in Chicago's western suburbs, undertook a leak detection project using acoustic sensors. Elmhurst is approximately 25km west of the City of Chicago; a beautiful, leafy neighbourhood.

The leak detection system assists property owners with leak detection. The system also rates resident's against others of similar details (family size, property, location, etc) so that they can see how their usage stacks up.

The sensors stick to the existing valves with a magnet, and contain a small antenna that sends data. The battery lasts approximately five to seven years in each sensor. The units talk to each other to assist in triangulating leaks to an accuracy of approximately three feet (one metre).

It is the largest fixed-based system in the USA, with some other cities having a similar system, but portable. This is the largest dedicated system for water leak detection.

Figure 30 – The City of Elmhurst City Hall

Prior to implementing the sensors, the city was paying 100%, but only receiving 80% in respect to their own water supply, with approximately 20% water loss prior to implementation.

The sensors have proven to be quite a success story for the City, saving significant quantities of water for their own use, and ensuring leaks are detected immediately. The city estimates that they have saved approximately $750k in water costs in the first twelve months alone, meeting the installation and initiation cost of the project.

The project consists of 605 sensors, installed at a cost of $750k. The system includes a customer/feedback system which can text customers to advise of leaks. This can be based on the ability of the system to drill down to the hour and identify abnormalities and continuous water use overnight. Feedback from users on these capabilities has been fantastic, with users previously unaware of existing leaks and rising costs, able to address the leaks and save money and water.

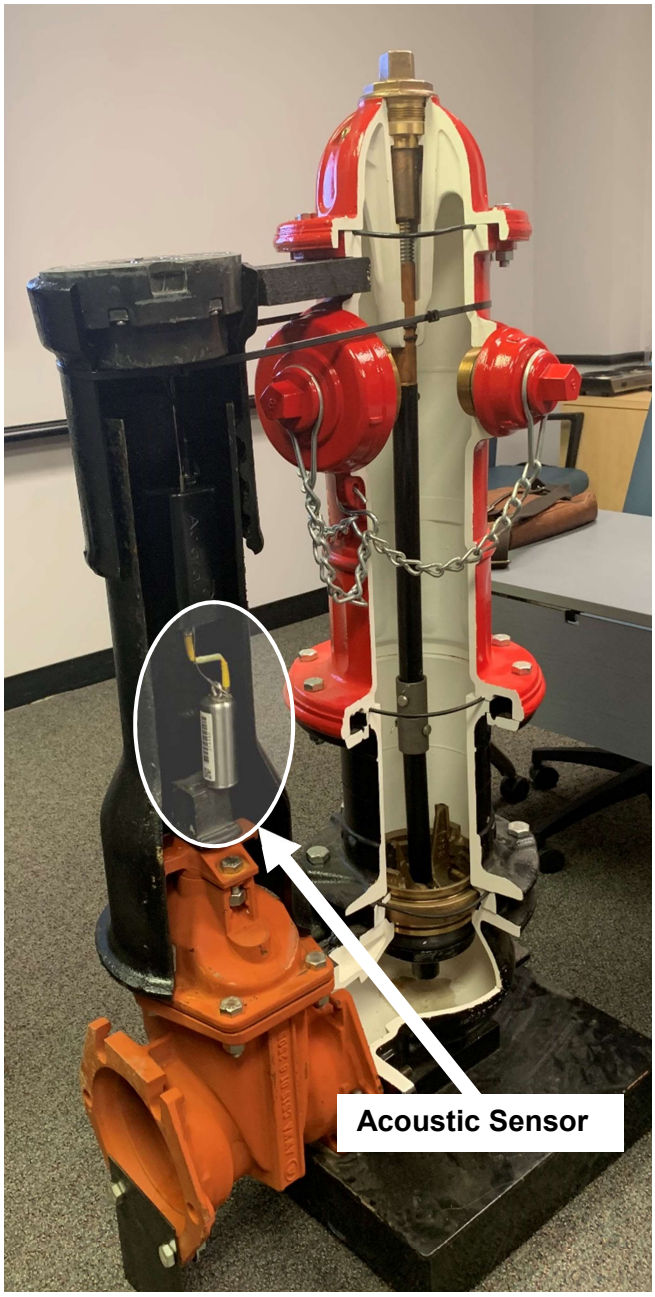


Figure 31 – Leak Detection Sensors – the black valves are under street level

The City was able to detect a significant leak, the result of a contractor using a hydrant for a sweeper, and failing to close the valve correctly, resulting in a continuous leak. The system was able to identify this immediately, and the City was able to send someone to investigate. It was able to be turned off immediately, saving significant volumes of water. Had this system not been in place, the leak could have gone undetected, resulting in water wastage and increased costs.

The City of Elmhurst is a high snowfall area, and snow ploughs can damage the valve lids. This can dislodge the antennas, rendering the sensors ineffective or useless. Similarly, some units were installed incorrectly, with the magnets on the side, or wires incorrectly installed. Following some trial and error, the City decided to install the antennas lower within the valves, which appears to have solved the problem.

Figure 32 – Dinner meeting with City of Elmhurst, local mayors and City Engineers

The software will plot onto the GIS, placing orange dots at possible leak locations for investigation, producing a detailed report. The system will send data once every six hours, arriving in a nanosecond. The meters also include a dry meter trigger – detecting if a resident has diverted their water. With this feature, the sensors are able to identify fraud and other problems.

7.1.4.3 Joint initiative between the Villages of Bensenville, Woodbridge & Lombard, IL

The team travelled to the Village of Bensenville, on the south-western edge of O'Hare International Airport, Chicago's major international airport. The three Villages of Bensenville, Woodbridge and Lombard, all located in a similar area, teamed up to meet with us to discuss a smart lighting trial recently undertaken, among other key topics. This trial was unsuccessful and it was very interesting to listen to the findings.

Bensenville were approached by ComEd (Commonwealth Edison Company), an electrical retailer in northern Illinois (a subsidiary of Exelon Corporation, the United States' leading competitive energy supplier) for a trial, and partnered with the Village of Lombard. The intent of the project was to upgrade high pressure sodium light fixtures to LED. 393 fixtures were replaced in Bensenville and 502 fixtures were replaced in Lombard. In addition, the aim was to test smart light technology and software. Two separate software systems were deployed: Light Grid in Bensenville and Streetlight Vision in Lombard.

Figure 33 – New Smart LED Light Sensors

The smart lighting system has the ability to dim lights to a set percentage, have real time communication, internal metering and the potential for a smart grid for other utilities.

The lights have the ability to communicate to each light individually, while having the ability to log into each light. The newer, more efficient LED lights look a lot better than the old lights, and offer many more energy savings.

The failures came with the software, which according to the team, never worked properly. The reports had to be manually generated, while there were security and login issues with the software provider. Only five people were provided with direct access accounts, however had experienced regular access issues and were unable to get into the software.

The trial was fully funded by ComEd, so the City was not disadvantaged by the trial. The City gained free LED lights out of the trial, which are far more efficient and have a longer life than the previous lights. The data issues experienced couldn't have been anticipated, the issues are very difficult to predict and protect against. This is where a trial delivery project works well in identifying potential and actual issues.

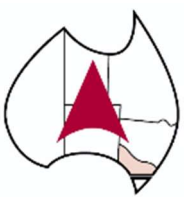
ComEd opted to go with the Street Vision Software, while Bensenville got to keep the 393 lights. It was pleasing to hear the lessons learned through the project from the team. It is important to note and expect that not every project has a positive outcome. ComEd's 'gift' of 393 lights to Bensenville was also a great way of offsetting the downside of failure. If the company had opted to remove the lights, not only would it have cost the company a lot of money, but it would not have been a good outcome for Bensenville who may not want to trial innovative products again. This solution provides a win for both sides, and leaves Bensenville wanting to innovate again.

7.1.4.4 Town of Wakefield, MA

The Town of Wakefield is located approximately ten kilometres north of the City of Boston, Massachusetts. The Town has a population of approximately 15,000 to 18,000 residents. The Town's community engagement is quite advanced, and they were able to provide many fantastic examples to the team.

The Town has developed a very engaged community, one which is consulted regularly, and has the opportunity to vote and make decisions.

Although not necessarily a failure, the Town has many committees and the community have the opportunity and ability to influence operational decisions. The Town can have between 500 and 600 residents attend a Town Meeting, an enormous number. While for a generic meeting, the lowest number of residents attending is generally about 50. Senior engineers and managers can spend four nights per week attending committee meetings, as well as Saturdays. This can have an impact on the work-life balance of staff.



Some committees and friend's groups will arrange and pay for some works, some up to the value of $200,000. The community then feel that they own the infrastructure, and although this is beneficial in respect to minor maintenance, it can generate complications.

Figure 34 – The team with staff from the Town of Wakefield, MA

Although good community consultation can be beneficial to municipalities, providing decision making processes can be disruptive. One example provided by the Town debated the design of infrastructure within the municipality, and the concern that the consultation can bounce between different committees and friend's groups, delaying projects. Delayed projects have been a regular occurrence, with one project discussed having been delayed by almost ten years before the design was finally approved.

7.1.4.5 City & County of Broomfield, CO

Broomfield is a suburban community approximately 25 kilometres north-west of downtown Denver, Colorado. Together with the City and County of Denver, Broomfield is one of only two combined cities and counties in Colorado. This brings with it many extra responsibilities including running a large correctional facility. In addition, Broomfield is going through a period of increased residential growth. This has placed pressures on asset management and maintenance.

Figure 35– The team undertaking a site tour with Kimberly Dall, Deputy Director Public Works at the City & County of Broomfield, CO.

At the time of meeting with Broomfield, they had recently begun a centralised asset condition rating inspection program, something that had not previously been completed. Some assets were tracked well, but in separate systems so coordination of maintenance and repairs was challenging. Other assets weren't tracked at all. As such, maintenance and repair activities were very reactive. The City and County are currently playing catch up, and with the proposed purchase of a new work order and asset management system this financial year, they are working hard to ensure their records are up to date. One of their priorities is to replace many of the metallic water pipes with PVC, as the soil in the area is rather corrosive, reducing the expected life of the pipes.

Their focus is proactivity, as opposed to waiting for things to fail. As an example of failures caused by lack of available data, the team discussed a recent stormwater failure experienced by a neighbouring municipality, and one which has provided excellent learnings. A quote from the team:

"It is valuable to use other's failures to demonstrate the need to undertake maintenance."

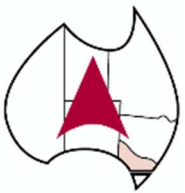
Regular and routine maintenance would have prevented the major failure experienced by the neighbouring municipality. The maintenance and repairs were estimated at between $20 million and $30 million, quite costly, however rectifying the major failure cost the city approximately $90 million.

This example importantly demonstrates the need to maintain accurate and up to date records of infrastructure, as well as current condition data. An improved way to do this is through Smart Cities infrastructure, which the team at the City and County of Broomfield are in the early stages of investigating and learning from others. They have recently implemented a smart irrigation system, controlled through a central smart controller, which adjusts to changing weather conditions automatically. They have installed a variety of sensors on local traffic signals, and they are investigating establishing a fibre ring around the municipality.

In addition, they are pushing for smaller vehicles to be electric vehicles, and adopting EV's as part of their own fleet.

7.1.5 Manningham City Council Smart City

Manningham City Council is located in Melbourne's north-east encompassing suburbs including but not limited to Bulleen, Templestowe, Doncaster, Warrandyte, Wonga Park, and Park



Orchards. Many areas within Manningham are wealthy, with large homes and properties spread throughout the municipality. The council also has one of the largest networks of open space within metropolitan Melbourne with approximately 17 percent of the municipality dedicated to open space including over 300 parks, gardens and reserves.

Figure 36 – The historic Pound Bend Tunnel, Warrandyte. The tunnel was constructed in 1870 to divert the Yarra River, so that gold could be mined on the river bed.

Manningham has been transitioning through a period of significant change over the last two to three years. Manningham Council's aim is to become Victoria's leading municipality in respect to technological advancements and innovation. Manningham has changed many of its systems and processes to accommodate the current innovative thinking approach, and provided space for its staff to innovate.

Manningham has partnered with the Australian Government through a grant received for Smart Cities infrastructure and technology through Council's Smart Cities – Reinventing Neighbourhoods program. The site selected for the smart technology is a local neighbourhood centre known as Jackson Court on Doncaster Road in Doncaster East.

The project at Jackson Court was well underway at the time of writing, and includes the use of parking sensors to gather data and information to assist the council to better understand how the community use the shopping neighbourhood. It will also assist in providing opportunities in the future for council to improve the community's experience when using the neighbourhood centre through analysis of the available data and targeted improvements. In addition, the sensors also assist with enforcement of parking limits through the use of electronic devices, and trend analysis.

In addition to the parking sensors, council is also undertaking research in the community to better understand how the community and visitors use the neighbourhood centre, how the

experience could be improved from this, and how the council can incorporate the finding into planning for the centre's future.

Smart sensors are also being installed around the neighbourhood centre to gather real time data from users. The data gathered will provide Council with detail on vehicle and parking patterns, pedestrian movement, and environmental and atmospheric conditions such as noise, temperature/weather, pollution, and more.

The data through the smart sensors will be gathered through the use of Wi-Fi wireless technology, engaging with the Wi-Fi on personal devices such as mobile phones. The data can be analysed through the use of measures such as heat maps, and manipulated to determine pedestrian movements at certain times of the day, or during certain events, or defined times at Christmas for example.

The data will assist the council to better understanding how visitors move around the centre, what their mode of transport is, how long they stay, where they go, what activities they undertake, etc. It will assist with better planning into the future, ensuring the council gets the right mix of space such as parking, infrastructure, facilities and open space to assist in making it a more attractive location for visitors to undertake their shopping and other activities at the centre. The trends can also be shared and utilised by local businesses and community groups to better plan for events and promotions.

The sensors do not collect or store any personal information, and utilise the unique Wi-Fi identification of each device to differentiate between devices, identifying return visits, movements and long stays such as dining. Similarly, the data will identify which establishments are visited, what the visitation rates are, time of day, how long visitation is and more.

This project marks the first Smart Cities project within Manningham, with the intention to undertake many more over the course of the next decade and into the future.

7.2 Innovation

Innovation in local government is an ongoing necessity. Municipalities must innovate and constantly change to keep up with a world changing around us. Innovative technology will also continue to evolve, creating opportunities for municipalities to innovate and change. Organisations must be ready for this change and innovation, and embrace it, not resist it. Organisations that resist this change will be left behind.

Change is becoming more and more rapid as technology improves and the world becomes faster and more efficient.

Innovation is key to adapting to rapid change. Organisations must focus on new ways of doing things, and in particular, innovative ways of doing things. Innovation is the key to organisations achieving positive outcomes into the future. Embracing our changing and rapidly evolving technological advances to inspire innovation in each organisation.

Smart Cities infrastructure is critical to future innovation within organisations. Smart Cities provides an established ‘blueprint’ as such, for organisations to adopt smarter ways to manage and maintain their infrastructure. Using Smart Cities as a starting point, organisations can begin their innovation journey, and establish themselves at the forefront of the industry. Getting the data capture and analysis right at the beginning is critical to this success. For Smart Cities to succeed, the right system must be in place behind the scenes to ensure that the data collected is able to be analysed and interpreted, and then displayed in an easy to understand format.

7.3 Leadership in Public Works

Throughout our study tour, the team met with some incredible Public Works leaders. Many of which created their own following of ‘supporters’. Their influence and leadership, particularly in the innovation space is inspirational, with Smart Cities being recognised and encouraged by all. This demonstrated firsthand the importance of leadership and providing the opportunity to staff to be creative and innovate. Given the influence these professionals had on the team, I thought it would be worth providing a brief write up on a selection of those we had the privilege of meeting.

The importance of leadership was evident to the team directly and through the team members working with those we had the privilege of meeting. I have selected only a few, however I could have included many. We met so many fantastic and influential leaders that it is simply not possible to include them all. We thank everyone for the time and effort put into hosting our team and showing us around. The level of hospitality received by the team was unexpected, and highly valued.

I will start with John Mick, affectionately known as Tex to most that know him. A man with an incredible drive and energy level. Tex is the Illinois Division Manager for Baxter & Woodman, a large consulting firm in the United States. He is also the APWA Chicago Chapter Chair for the International Affairs Committee.

Tex provided great assistance to the team through research for the tour, being responsive and ambitious, assisting the team through the many contacts available through APWA, as well as his personal network. This assistance was provided not only for Chicago, where Tex is based, but for all cities visited by the team.

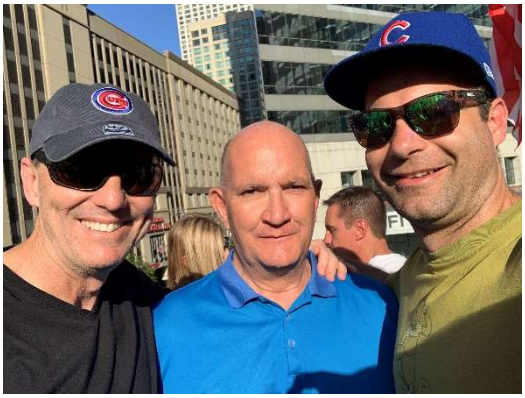


Figure 37 – Tony & Kurt with Tex after attending the baseball at Wrigley Field in Chicago, IL.

Tex inspires those around him, and if a question he does not know the answer to is put to him, he will waste no time in seeking an answer for you.

Chris Osgood, Chief of the Streets, Transportation and Sanitation at the City of Boston, has a unique vision for continuous innovation. His team are constantly inspired through Chris and his leadership team to innovate and think of different ways of doing things. As Chris explained, it is important to provide space for your staff to innovate. Chris achieves this by ensuring his staff have the capacity to undertake their role, and spreading the workload fairly, ensuring they have enough time available to seek out innovative ideas, investigate, advocate and pursue them.

It was clear through our visit to the City of Boston that Chris's team admire him, and place a lot of trust in him. He is a quiet achiever with a contagious vision for achieving the best through everything he does. Chris is pictured in **Figure 14**.

Steve Townsend, City Engineer at the Portland Bureau of Transportation (PBoT), a division at the City of Portland, Oregon provides excellent leadership to his dedicated team. In a similar way to Chris Osgood, Steve is innovation focused and leads his team to strive for the best. Steve inspires those around him to seek the best way to achieve things, and encourages innovative thinking.

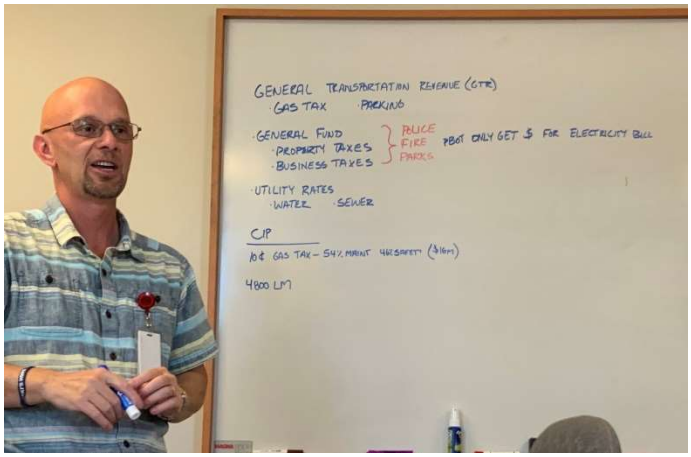


Figure 38 – Steve explaining PBoT's funding sources

Figure 39 – The team meeting with John Lewis and his team. John is at the rear of the photo

John Lewis at the City of Oregon City in Oregon demonstrates caring and empowering leadership. Although quite laidback, his team are constantly empowered and encouraged to innovate and improve. Through recruitment, John will seek the candidate with the greatest drive and passion, and build on their knowledge and experience. This is evident through many of the staff currently working within John's team.

John has been able to achieve his visions through his staff, all engaged based on their ability to achieve a desired outcome and their drive and stamina to overcome hurdles and fulfil their required tasks. John has a dynamic team that go above and beyond to achieve the vision of their inspirational leader.

Dan Kaup at the Village of Lake in the Hills, Illinois is another leader inspiring great things within his team. Dan's knowledge in asset management is extraordinary, and he shares this knowledge with his team to achieve great results in the asset management space. Dan is also an active member of the Fox Valley branch of APWA.

Figure 40 – Kurt presenting Dan Kaup with an appreciation plaque

Kimberly Dall from the City & County of Broomfield in Colorado is another leader that went above and beyond for our team. Kimberly, also active in the Colorado chapter of APWA, provided incredible leadership to our team, as well as her own through the facilitation of a number of meetings and site visits. Kimberly leads a dynamic and supportive team. Her enthusiasm and dedication ensures her ventures are generally successful, while maintaining a robust work culture and high morale within the public works department at the City & County of Broomfield. Kimberly is pictured with the study tour participants in **Figure 35**.

Dan Hartman from the City of Golden, Colorado is another example of an exceptional leader. Softly spoken and incredibly polite, Dan was the driving force who facilitated the team's tour of the fascinating NREL facility. Without Dan's fantastic leadership and tour lead capabilities, the team would have missed an amazing opportunity to undertake a site tour through this magnificent facility. Although the team did not have sufficient time to visit Dan at the City of Golden, Dan made extra allowances for our team through facilitation of evening drinks and the NREL tour – which I must add is very difficult to get into.

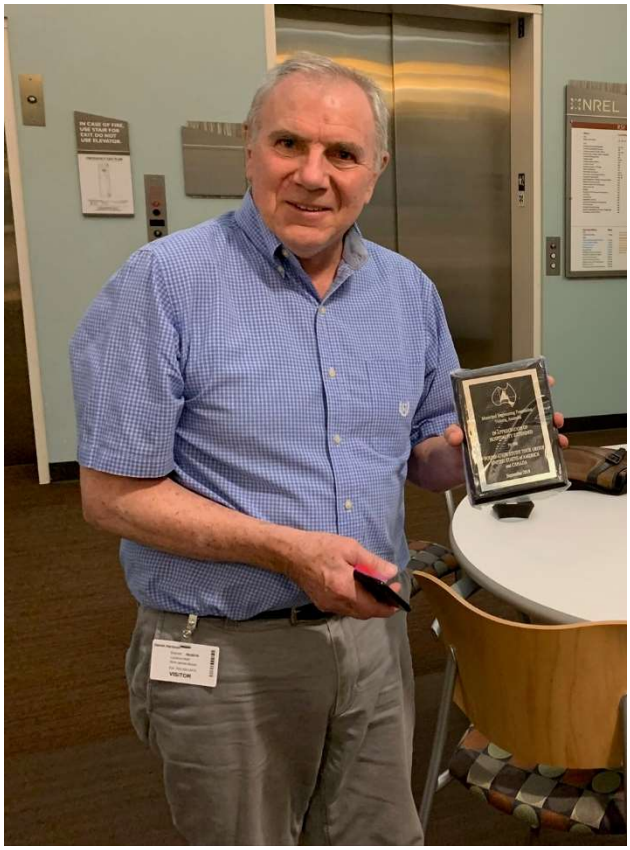


Figure 41 – Dan Hartman after being presented with an appreciation plaque

Although this is only a snapshot of some of the amazing leaders we encountered, it highlights and reinforces the importance of leadership at all levels in an organisation and community in delivering outstanding public works outcomes.

8. Using Technology in Asset Management & Maintenance

How can we use all this technology to better manage our assets? What are some of the ways this technology is currently being used to better manage our assets?

Through some of the examples and experiences detailed in this report so far, it can be seen that many organisations through the United States are currently utilising technology to better manage their assets. The team met with many organisations currently undertaking trials of innovative and smart technology.

The City of Boston discussed a fantastic innovation brought forward to them by a former army officer. The proposal was for snow micro forecasting, the ability to forecast the difference in potential snowfalls between different city blocks. This was an excellent innovation, but is it really solving a problem? Or is it a solution in search of a problem? The City of Boston determined that the technology was great, but it wasn't going to change the way they operate and was not worth investing in. They wouldn't adjust their snow plough patterns based on this data, and determined that even if one street received more snow than another, their snow ploughs would still be operating and would complete the required task. The team felt that it was inefficient and unrealistic to expect this level of service, and the results of the forecasting would not alter the City's snow plough patterns.

This highlights the importance of the existence of a problem in the first place, prior to seeking out ways to solve a non-existent problem, potentially creating more problems in the process. Technology is developing very quickly, and there is a vast array of products and/or services searching for a problem to solve. This can often be the wrong way around. In many cases, solutions should be designed around problems, ensuring the problem is thoroughly investigated and addressed, with a solution being tailored to the issue at hand.

Does your agency have a current asset class that could be managed better? Smart Cities technology can assist agencies in their management of assets in a smart and efficient way. Or do you have the need or desire to understand the use of your facilities better?

The recent example of a project undertaken at Manningham Council utilising a combination of simple parking sensors and atmospheric sensors to collect and analyse data demonstrates how this technology could be beneficial to agencies. This data allows the team to analyse a

large array of useful data and information relating to the particular location at Jackson Court shopping precinct.

The data is collected from the parking sensors in the pavement and the atmospheric sensors, transferred to a database, analysed and interpreted into useable data. This can be presented in graphs, tables, heat maps and many other ways to identify trends and usage patterns. The information can then be utilised from a maintenance and management perspective to plan for the future use of the facility.

For example, parking usage patterns can be better understood, and parking limits adjusted to better suit the usage of the facility. Similarly, the expiration of one's parking space limit will alert nearby parking enforcement officers, and enforcement can therefore be conducted efficiently.

The pedestrian data can be utilised to determine usage patterns and visitation frequency. It will paint a picture showing how often individuals visit a facility and which locations are visited. It will show how many and which sites are visited by each individual with each trip. It can interpret detailed and sophisticated patterns to show where users, for example, may visit for a haircut, followed by a coffee or lunch break with friends at one of the restaurants or cafes, or general parking utilisation in relation to evening restaurant usage.

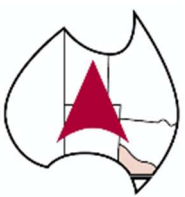
The data obtained from the atmospheric sensors can be combined with the parking and pedestrian data to understand how the changes in weather and events impact the usage of the facility.

The data can also be used publicly to identify available parking spaces to users through electronic signage and the use of applications. Simple usage patterns could also be released so that visitors could plan their trips for the quietest periods of a day.

The possibilities are almost endless.

There are emerging ideas and trials relating to specialised sensors in road pavements. These sensors could assist the asset manager in the long term management of the pavement by delivering data relating to the condition of the road surface and underlying pavement, assisting the asset manager with maintenance and renewal planning for their asset network into the future.

Using data in this way will assist in the understanding of the remaining life of infrastructure, and have the ability to break the data up into different categories.



9. Additional Research & Findings

The purpose of this chapter is to provide additional detail on some of the more interesting parts of the study tour which may not be directly related to my topic.

9.1 National Renewable Energy Laboratory (NREL)

The National Renewable Energy Laboratory, or NREL as it is commonly known, is a facility on the outskirts of Golden, Colorado; an outer western suburb of Denver and tourism destination. The facility has been operating since 1977. It is a government-owned, contractor-operated facility funded by the United States Department of Energy. It is a research facility with approximately 2,000 staff – of those, approximately one third hold a PhD, many others are working towards one, and several staff hold the Nobel Prize. It is a sophisticated and highly technical research facility and access to tour groups is difficult to obtain. Our team were very fortunate to have the opportunity to visit this spectacular facility.

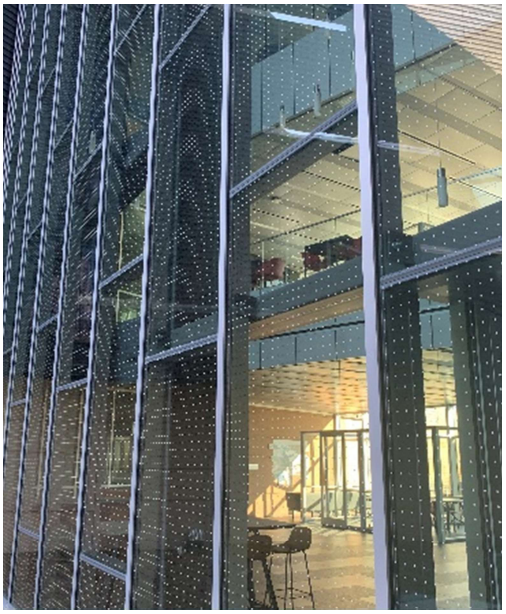


Figure 42 – Window 'dots'

The campus is as environmentally sustainable as was attainable at the time of each expansion. Retaining walls and barriers are made with gabions, filled with rock excavated from the site. The gardens are extensively planted with indigenous flowing plants, shrubs and trees to attract and encourage bees and native wildlife. Around the building, swales and many other WSUD features have been incorporated to assist in managing stormwater runoff and treatment. The buildings were constructed with an extraordinarily high amount of recycled materials; the team confirmed that the highest amount of recycled material possible was incorporated into the facility. Many of the windows have been installed with small decal dots – a unique and effective design objective, which not only adds to the character and aesthetics of the building, but prevents birds and bats from flying into the glass and injuring themselves.

The facility has invented electrochromic glass, which has been incorporated into many of its windows. This technology has also been installed on the new fleet of Boeing 787 Dreamliner

aircraft, which the team were fortunate to learn about on a tour of the enormous Boeing facility in Everett, north of Seattle in Washington State on our way to the conference. Electrochromic glass works by tinting, or changing the colour or opacity of the glass when a certain charge is applied to it. For example, on the 787 Dreamliners, which the team also had the privilege of travelling on for the journey from Melbourne to Los Angeles, the windows include an up and down button underneath with an accompanying LED indicator panel. By operating the control, one can control the level of tint within the widow, and effectively 'black out' the window, eliminating the need for window shutters. Control of all windows can be overridden by the flight assistants if required, for example in the case of an emergency, or when landing.

Figure 43 – Electrochromic windows – Boeing 787 Dreamliner

The technology is well established, with elecrochromic windows now available for commercial and residential installation. There are Australian companies marketing the product, targeting all industries. Effectively, the technology has the ability to automatically adjust to the light, acting like a pair of sunglasses around your home or building, increasing energy efficiency.

Another sustainable feature incorporated into the design of NREL is the solar generating windows. SwitchGlaze is a very new product, a switchable photovoltaic (PV) window. Testing of the product is ongoing at NREL with the intention to eventually introduce it to the industry as a product ideal for residential properties, and glass-covered skyscrapers alike.

A paper titled *Switchable photovoltaic windows enabled by reversible photothermal complex dissociation from methylammonium lead iodide* published 23 November 2017 provides data through trials, validating the technology for possible use into the future. The paper is quite in depth and goes deep into the scientific details of the technology, presenting the technology as a feasible option for future expansion of PV technology beyond rooftops and solar farms. A link to the study can be found in the bibliography.

NREL incorporates many environmentally sustainable features, and in addition to those already mentioned, includes facilities to capture the heat generated from the enormous supercomputer, as well as extensive rainwater capture and reuse throughout the facility. The image to the right shows the sleek design of the supercomputer, contained in a large room with many other specialised computers and technology.

Figure 44 – The main section of the supercomputer

One interesting avenue of research being undertaken by NREL is hydrogen fuelled vehicles. This is currently under development and photos are not permitted within this part of NREL as research is still being undertaken. The image below however, was taken and used with permission, showing one of the NREL security vehicles in the visitor carpark, which runs on hydrogen fuel.

Figure 45 – Hydrogen fuel vehicle – NREL visitor carpark

10. APWA PWX 2019 Conference

The team attended the 2019 Public Works Exposition (PWX), run by the American Public Works Association (APWA) in Seattle from Sunday 8 September to Wednesday 11 September 2019. PWX was a conference and expo of enormous scale and extremely well organised. Compared to any conference in Australia, including the IPWEA (Institute of Public Works Engineering Australasia) IPWC (International Public Works Conference) which in itself is enormous, PWX is phenomenal in scale. PWX dwarfs any other conference I have been to, and every effort has been put into the conference to make it the best.

The conference commenced with a meeting at 7am on Sunday 8 September for first-timers and new members. Several sessions were underway prior to official conference proceedings kicking off at 10am with an outstanding welcome show, followed by the first plenary session, an absolute eye-opener with Rex Hohlbein titled Facing Homelessness. Rex gave a very emotional presentation on the work he has undertaken and continues to undertake in Seattle to tackle the homelessness problem.

Figure 46 – Part of the enormous conference ballroom

Given our different topics of study, the team generally focused on separate presentation opportunities and selected topics closest to the chosen study topic, ultimately sharing notes between each other. We each attended many interesting and knowledgeable presentations.

The conference structure was well set out, with strategic and generous breaks structured into the program, allowing delegates the opportunity to network and visit exhibitors. The team took the opportunity throughout the conference to meet new people and gain connections through the field. There were a number of evening and lunch events organised which were excellent opportunities to further network and gain new connections.

The Get Acquainted Party on Sunday evening at the Museum of Pop Culture in Seattle, the famous museum dedicated to Seattle's strong musical and pop culture influence, was an extraordinary event. A great opportunity to further network in a relaxed and entertaining environment with live music, food and drinks, while exploring the museum's many interesting exhibits. Similarly, Monday and Tuesday evenings had equally impressive events, with Monday evening being dedicated to the international delegates and APWA officials at the Hard Rock Café, where musical memorabilia adorned the walls, another example of Seattle's strong musical history.

Tuesday evening, the traditional Chapter Dinners were held at various venues. Traditionally, MEFvic visitors will be hosted by the Chicago Chapter, and this year the dinner was held at the renowned Space Needle, a monument to the World Fair of 1962. A great opportunity to network with professionals from the Chicago Chapter, many of whom we were to meet when we arrived in Chicago the next day. The Space Needle is a remarkable structure, with incredible views over the city. The dinner was held in the function lounge, and the attendees later ascended to the observation deck for a magnificent view over Seattle at sunset.

There were many Smart Cities and innovation related presentations, including several around the topic of EV and AV. The team split to try and absorb as much information as possible from these fascinating and informative presentations.

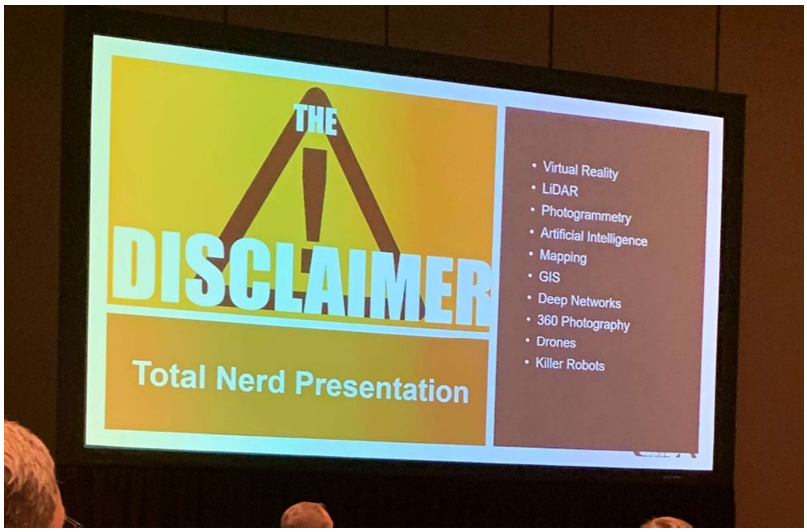


Figure 47 – A light-hearted presentation introduction

The exposition was enormous. The exhibit floor was so big, it was not possible to visit each exhibitor. Some exhibitors provided some fantastic information and demonstrations. Simulated displays were included, allowing visitors the opportunity to drive a snow plough or other machinery.

Figure 48 – Kurt operating a simulated snow plough on the exposition floor

Monday's General Session – Master Your Mind & Memory with Jim Kwik was fascinating. We learnt ways to adjust our thinking and learning to improve our memory.

Some of the Smart City and innovation presentations were very interesting. The City of Bellevue, east of Seattle, presented their Smart City Vision & Plan. It was very interesting to learn how a small municipality has taken the lead in Smart City technology and undertaken many trials.

PWX is an excellent opportunity to network amongst others within the industry. Networking amongst peers is incredibly valuable, and PWX is the largest and most valuable opportunity to do so. The opportunity to learn from fellow public works colleagues within the industry is valuable, with some very interesting and informative sessions available to learn from, while the

Figure 49 – Part of the enormous exposition floor

ability to chat to the presenters offers a unique opportunity to further connect and learn from their experience and expertise in the subject matter.

I often regard the networking opportunities and learning experience of conferences as some of the most valuable aspects of attending a conference. I also believe that attendance by younger engineers, particularly those within the first ten years of their career is important. Younger engineers should be encouraged to attend, and where appropriate, nominated by their leaders. The experience they gain, and we all gain from these conferences cannot be underestimated. To summarise some of the benefits to encourage professionals, particularly younger professionals to attend further conferences into the future, and possibly PWX further into their career, I have compiled the following list of benefits:

- Networking benefits
- Development of leadership skills
- Updated information on key issues affecting the industry
- Allow delegates to interact with other delegates who may be experiencing similar issues and problems in their organisation
- Access to key research and the latest information

- If located outside the city they reside in, the opportunities to explore the sights and sounds of the location
- Newest and most innovative products on display
- Innovation demonstrated through key presentations
- Opportunity to win prizes from the exhibitors
- Sharing of good ideas between delegates

Figure 50 – Tony, Lachlan & Kurt at PWX

11. Conclusion

Smart Cities, a reasonably young term within our industry, is beginning to establish itself as two simple words used to describe innovative ways to utilise technology and sensors to gather data.

Smart Cities is growing rapidly, and becoming more widespread amongst the industry. This is a good demonstration of the industry's desire to innovate, improve and change. The change is occurring rapidly, and our industry must ensure this is planned for effectively, making use of the technology in a smart sense and ensure cost-effective and efficient implementation of this technology, and not blindly implementing projects of no value because it is the new 'industry trend'.

Through the rapid growth of Smart Cities, agencies may be in a position where they are caught off guard by advancements in this technology and the industry's desire to innovate. Effective planning must occur in advance to ensure agencies are ready for this change in technology. Planning is important to ensure that agencies are prepared. To ensure that projects are implemented with the data usage in mind, projects should be planned from an asset management perspective. How can gathering complex data and information help me better manage my infrastructure? How can additional data assist me in understanding how people move around a complex or facility?

Smart Cities can be a very powerful tool in asset management and maintenance, if used to its full capacity. This can only be achieved if it is thoroughly researched and collaboratively implemented across the agency. This means breaking down those traditional silos within agencies, and in particular municipalities, and improving communication between teams. Working together for an improved outcome for all stakeholders has never been more important.

Utilisation of public engagement and consultation is critical to the implementation of new ideas, and more specifically, the ability to undertake trials. Ensuring transparency, particularly to those directly affected or involved in the trial being proposed is important to ensure the trial's success. Prevention of negative feedback and publicity associated with new ideas is important. Negative publicity can greatly affect an agency's ability to undertake trials of innovative products and services. Failure, without the appropriate information being provided to the community, can be catastrophic. Failure, with sufficient information in relation to the benefits, and rectification should a trial fail, can be utilised as a positive outcome, with little to no negative feedback.

Appropriate consultation, including clear and concise information on the benefits to the agency, and in particular the Council, reduced maintenance costs and frequency, and more importantly, the benefits to the residents and/or public is important. Providing these details up front, and ensuring the community have few unanswered questions is critical in preventing negative publicity. Agencies have the ability to utilise the community to support their ideas, providing that appropriate information has been provided to them, and thorough consultation has been undertaken to ensure that they are on-side.

Similarly, internal engagement is another important aspect. Involving your communications team, as well as other appropriate teams such as maintenance and procurement will assist you in your endeavours, and ensure that the project is a success.

Opportunities should be sought where available. Involvement with companies at the forefront of technology and ideas is important, but must be done equally and fairly, ensuring compliance with the *Local Government Act*. Taking opportunities as they arise and working with educational institutions will help drive this technology forward, and ensure Smart Cities is seen as a positive and advantageous form of technology. It can be sold as something that greatly assists your agency in understanding the data associated with the condition and/or usage of infrastructure, and therefore improvement opportunities can be identified and communicated to the public and/or users. The benefits could save money or provide greater improvements by other means.

Undertake trials, utilise new products. Monitor, test and record the results regularly. Publish the results and participate in conferences and information sharing. Be open and contactable, ensuring your counterparts in other agencies feel comfortable approaching you for information and knowledge. Invite them to participate in site visits with you and witness some of your trials.

Know your agency's procurement policy. Understand it and ensure that you work within the policy and the provisions under the *Local Government Act*, if working in local government. Many new ideas will not yet have established competition, and procurement exemptions may need to be sought. This should be thoroughly understood prior to embarking on a trial.

Most importantly, start the journey. Begin now by reading your procurement policy, speaking with the decision makers in your organisation. Garner support for innovation. Research opportunities, speak with industry leaders and educational institutions. Understand your

Figure 51 – The team enjoying some downtime at the baseball at Fenway Park in Boston, MA

agency's culture and level of support. Be the advocate for 'doing things better', for managing your assets more effectively and efficiently. Understand the benefits associated with using technology to improve the way your assets are managed and communicate this clearly.

Strong and varied leadership is critical to your organisation's success. As detailed throughout this report, the value of leadership cannot be underestimated. Ensuring you have a strong and varied mix of effective leaders within your organisation will ensure your success when seeking to explore Smart Cities options, and ensuring your desire to innovate has a great chance of success. Seek a champion for key leadership roles, and recruit based on the individual's leadership strengths. Further encourage staff to become leaders in their own space, empower the staff to explore innovative ideas, and develop resilient leaders through effective leadership.

As demonstrated through the many strong and influential leaders encountered throughout the study tour, success and organisational culture are directly influenced by the leadership within an

organisation. Where a dynamic and empowering leader was present within an organisation, this was reflected through the morale and energy of the staff working within the team. Those staff were excited to come to work every day. Their achievements were valued and recognised. They were encouraged to seek innovation and supported through their ideas.

The importance of leadership was evident to the team directly and through the team members working with those we had the privilege of meeting.

Further, the sharing of knowledge, particularly through influential and inspiring leadership is encouraged amongst organisations. Successes shared between organisations can assist with further empowerment and successful implementation of innovative ideas.

In closing, I would again like to acknowledge and thank MEFvic, and my employer Manningham Council for their support and encouragement. Without their support and encouragement, this report would not be possible. I would also like to reinforce the value and importance of the study tour. I strongly encourage other Victorian Public Works professionals to consider applying for a future opportunity. The experience and learnings brought back from the study tour were exceptional, and simply cannot be compared to local experience gained through professional development opportunities. Participation in PWX cannot be beaten as far as networking opportunities, and sharing of knowledge go, and the study tour provides a unique opportunity to combine attendance at this fantastic and well organised conference with learning opportunities from the study tour. Participation in a future study tour will greatly expand the participants experience and knowledge through the experiences gained and assist greatly in their future career progression, while gaining further value out of their current role.

12. Recommendations

Based on my observations from the study tour, and further research and findings, the following recommendations have been summarised:

ALTERNATIVE TRANSPORTATION

I. Plan in advance to accommodate alternative transportation

Through master planning and project development, ensure alternative transport options are accommodated. Plan for increased bicycle and eScooter usage, and plan for future docking stations. Incorporate AV infrastructure into future planning.

II. Plan and build for AV & EV's – build the infrastructure now, rather than retrofit later

Look at opportunities to incorporate EV charging stations where projects are planned, as well as improvements to allow for AV. For supermarket car park upgrades, plan for EV charging stations, and AV driving and parking. For planned works and major maintenance activities, investigate and explore how road alignments could be improved to allow for AV technology and further assist future implementation.

SMART CITIES & INNOVATION

III. Actively seek & participate in innovation trials – engage with suppliers & industry

Stay abreast of industry innovation options and new products hitting the market. Thoroughly undertake your own research and ensure all information available has been absorbed and summarised for others within your organisation (as well as the community). Seek out involvement in trials and new products. Implement on a small scale. Provide staff with sufficient time to seek out innovative ideas. Keep in touch with research institutions and industry leaders, and work together to explore trial options within your own municipality.

IV. Share innovation trials & wins – promote amongst industry & community

Share success stories through your community. The public obtain benefit from success stories, and will support further trials and innovation providing community consultation

has been engaging and informative. The community are key to continued innovative success.

Write papers for magazines and conferences – share the information with the industry. Invite other municipalities to participate and witness your own innovative projects through transparent information sharing and open site visits. Provide support through your own learnings and knowledge to others in your industry; be open to sharing your own failures and how your successes have come about. Sharing of information can greatly assist innovative success stories, and allow a support network for innovation on a greater scale within the industry.

V. Continue experimentation

Stay abreast of industry information and new products. Look for opportunities for experimentation through your day-to-day role; look for better ways to achieve things, and ways to promote your business or municipality. Take baby steps, start small and focus on undertaking small-scale trials, and upon success, increase the scale for the next project or further trial. The importance of starting small cannot be overlooked – failure on large scale trials can be catastrophic and limit the organisation's ability to innovate in the future. Failure on small scale trials can be a learning point, easily rectified and improved upon. And if sold adequately through effective community consultation, further trials are more likely to be supported by the community.

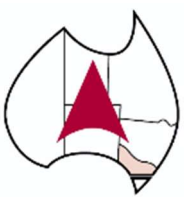
VI. Recruit the right people

Recruiting staff that share your vision for innovation and smart cities is important to the success of your vision. Recruit staff for their hunger and desire to innovate and change, for their openness and willingness to learn, rather than their overall experience alone. Seek the right staff to ensure success through innovation.

USING SMART TECHNOLOGY IN ASSET MANAGEMENT & MAINTENANCE

VII. Develop policies and procedures to guide data capture & usage

Initiate the development of policies to guide the process of data capture. Existing policies may be utilised to establish a research base to develop your own policies, ensuring understanding. Having policies and procedures in place in advance can be beneficial to ensure consistency and greater understanding prior to embarking on smart technology



projects. Providing guidance in the usage of the captured data can be equally as important to ensure there is a clear plan in place prior to beginning data capture – why begin capturing data if we don't know what we are going to use it for? Or how we are going to use it/how it will benefit us?

VIII. Establish a 'Smart City Lead' within your organisation

Identify and establish a Smart City Lead to drive the ideas, collection and analysis of data. This lead will be the driver for projects, and how the front end (smart city projects & data capture) benefits the back end (asset management data and planning). Ensure there is a need for data prior to funding and initiating a project without a purpose.

Figure 52 – The vehicle shelters at Panasonic City NOW – consisting of PV Panels

Figure 53 – The vehicle shelters from above

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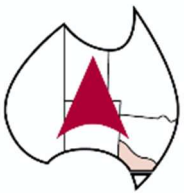

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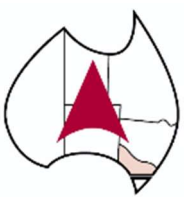

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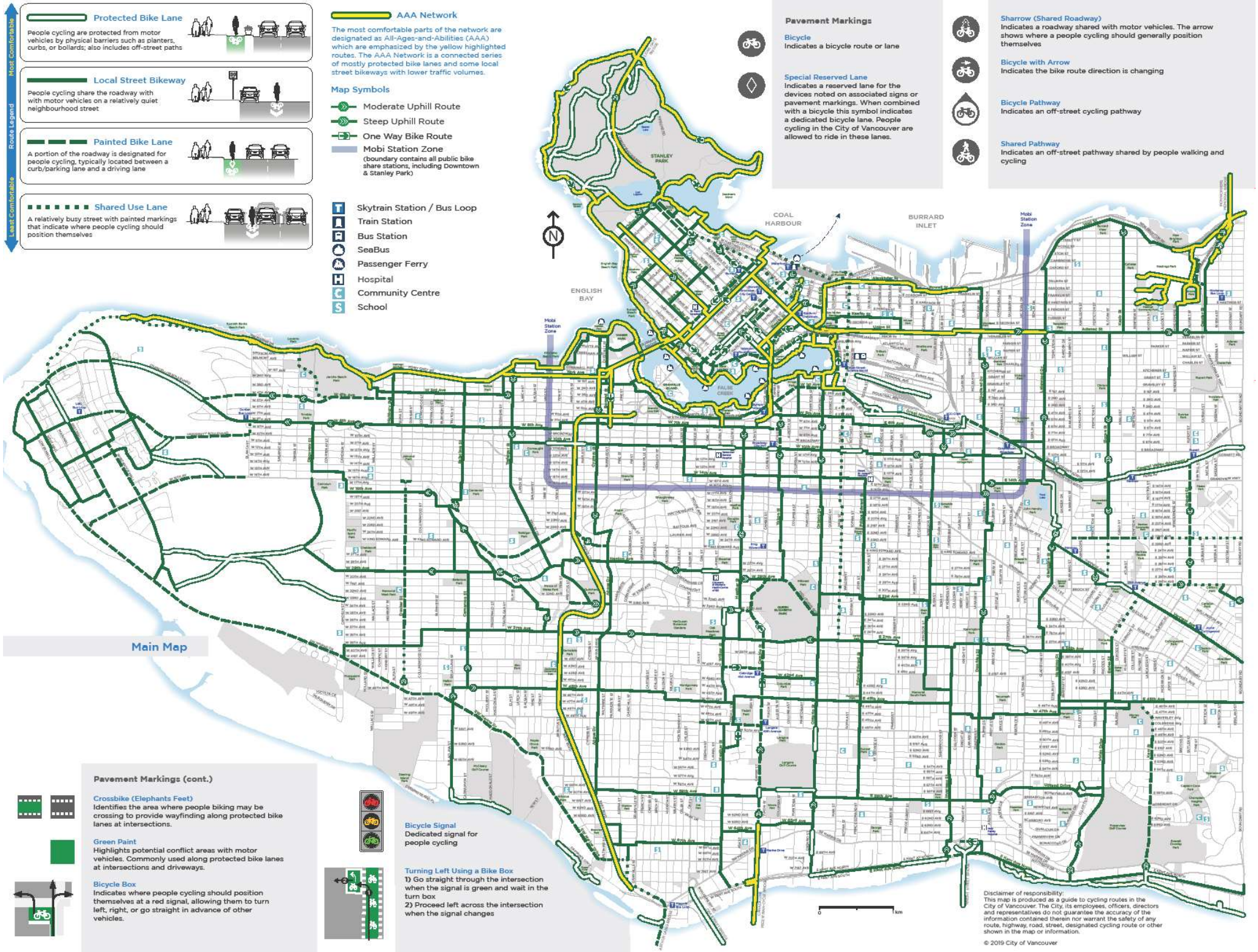
Figure 54 – Harvard University Library

14. Appendix

A copy of the Vancouver Cycling Map is included overleaf



Disclaimer of responsibility:
This map is produced as a guide to cycling routes in the City of Vancouver. The City, its employees, officers, directors and representatives do not guarantee the accuracy of the information contained therein nor warrant the safety of any route, highway, road, street, designated cycling route or other shown in the map or information.