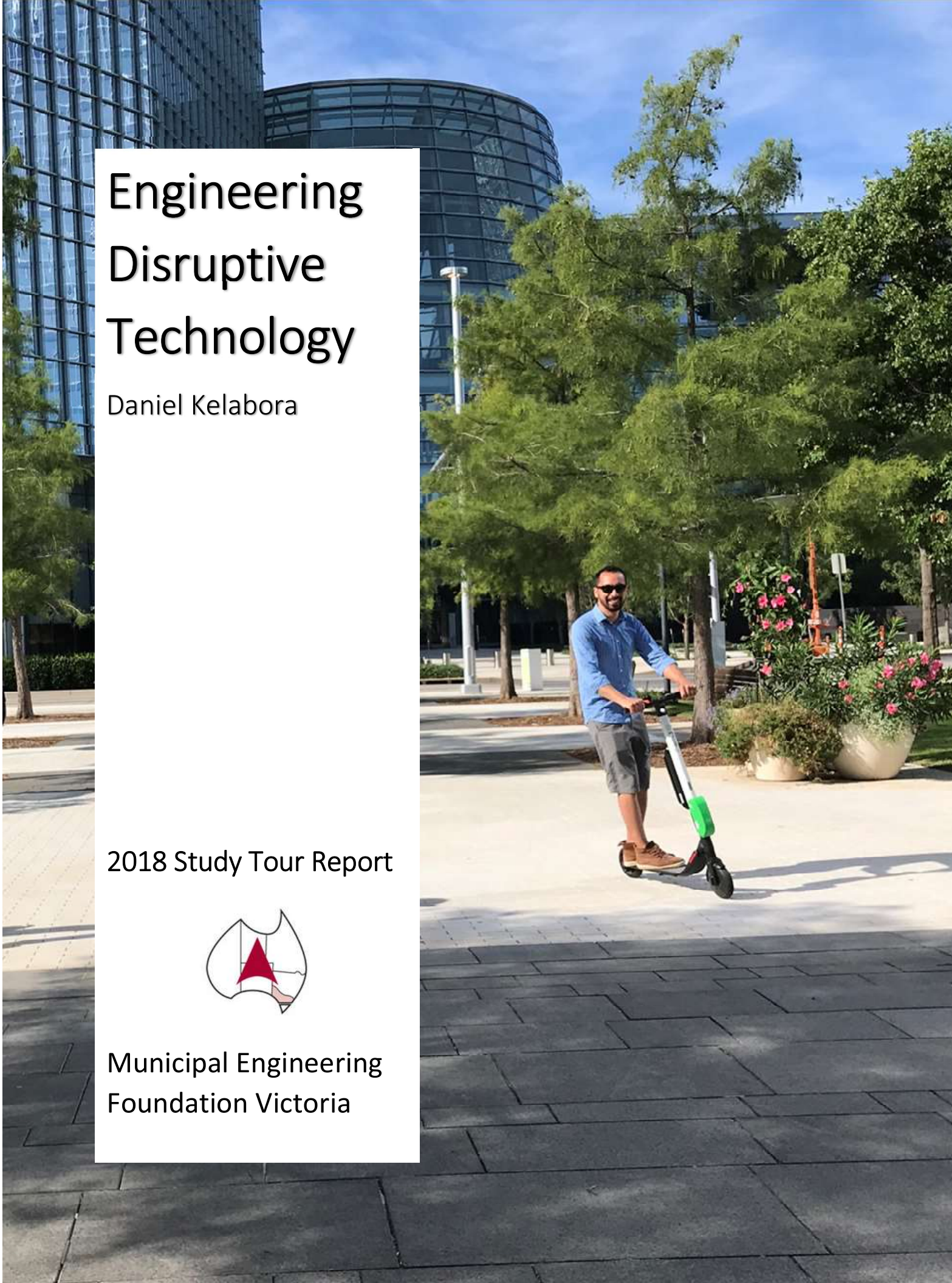

Engineering Disruptive Technology

Daniel Kelabora

2018 Study Tour Report

Municipal Engineering Foundation Victoria

1. FORWARD

1.1. Acknowledgement

This report has been made possible by the support of the Municipal Engineering Foundation Victoria (MEFV), which provides the amazing opportunity for public works professionals to build their technical and managerial skill through an international study tour scholarship each year. The generosity of the foundation is without peer and the legacy that it continues to build will be enduring both here and overseas.

Particular thanks to Geoff Glynn, Claudio Cullino, Merv Patton and Mark Varmalis from the foundation whom prepared and support us throughout the tour.

The generosity extended to us by all the study tour locations was astounding. The welcome, information sharing, and time together exceeded all expectations.

Thank you to Latrobe City Council and Manningham City Council for encourage my application and supporting my time away from day to day duties.

1.2. Tour Delegation and Topics

MEFV Trustee - Claudio Cullino – Director MECC Consulting

Advanced Waste Processing - Les Stokes, Manager – Operations, Melton City Council

Engineering Disruptive Technology - Daniel Kelabora, Senior Project Engineer, Latrobe City Council

Growing Leaders - James Kelly, Manager Delivery and Assets, Banyule City Council

1.3. Study tour itinerary

The primary stop on the study tour was the American Public Works Association's (APWA) Public Works Exhibition 2018 (PWX18) which was held in Kansas City. Other cities around Kansas were then selected to balance itinerary and relevance to each of the three topics being investigated.

The cities included in the study tour were:

- Edmonton, Alberta, Canada
- Minneapolis, Minnesota, USA.
- Kansas City, Missouri, USA - Host of APWA PWX18
- Oklahoma City, Oklahoma, USA
- Tulsa, Oklahoma, USA
- Houston, Texas, USA.
- Austin, Texas, USA.
- Frisco, Texas, USA

2. EXECUTIVE SUMMARY

Will a computer take my job? As a young professional in the public works field the uncertainty about the impacts of Artificial Intelligence (AI) on my future in the profession and industry led me to ask this question. To understand it I investigated how the public work profession is responding to other technological disruptions and drill down on how an Engineer's role might change with Artificial Intelligence. To begin I explore current innovation trends in shared mobility and data and the Agency response.

Shared mobility is a competitive industry with Autonomous Vehicles (AV) trials and Dockless electric scooters (e-scooters) seeing widespread deployment to varied levels of success. Where legislation permits Level 4 AVs have been undertaking trails on open public roads to introduce the public to the value proposition they offer. The City of Frisco drive.ai trial was exciting to take part in by seeing how a fully autonomous vehicle can navigate its way through live streets with its array of sensors. It demonstrated that the bigger barriers for AVs are regulatory or social rather than technological.

At the same time e-scooters have been deployed without regulatory oversight and lead to poor community outcomes in some cities, even leading them to be deemed a public nuisance in San Francisco. Cities visited on the tour were not on the cutting edge but we were lucky enough to have time to be advised on the lessons they had learnt which were:

- Ordinances to control total numbers
- How they are used and parked in the road reserve
- Guidance or training for e-scooter users
- Managing equity of access
- Requiring trip data or investment in infrastructure

The benefit to local government from these forms of shared mobility technologies are tremendous but careful management of implementation, with public works working closely with providers, is the key to unlocking the benefits without the pains. This highlights the importance of Professional networks like APWA and IPWEA acting as the locksmiths that share the learnings across the industry to adapt together.

Industry 4.0 is taking root across the sector with data being harnessed to improve service delivery and outcomes for communities. Savvy agencies are coding their own software to integrate existing data sets and improve processes and decision making. Open data is allowing the data value chain to be extended beyond city administrators which is creating new business opportunities and citizen experiences. Interestingly, the first beneficiaries of open data are the public works agencies themselves as previously siloed departments open their data allowing for greater collaboration between departments.

It was acknowledged that public works data was public data and should be accessible. The added benefits of leveraging community resource to process data is that it reduced resource requirements within the agency itself and often the specialist technical skill lay outside the agency - such as a start-up entrepreneurial community that build apps as core business.

To understand where you agency stands and wants to move, three smart city models are put forward; the Clockwork City; the Open City; the Emergent City. Though they are not an evolution and instead coexist there are enablers for each of the models that were identified through the tour.

Champions and systems build Smart Systems within the Clockwork City. This is the natural model for public works with a rigid hierarchy and decision making process.

An Open City grew from community demand and or an organisational vision. Then supported by strategy, policy and investment in platforms and people created the citizen centric Smart Communities that place operational transparency at the heart of business.

Finally within tech precincts that supported a tech industry and community, a collaborative agency culture to search for the best overall delivery of a service was the hallmark of a Smart Ecosystem of the Emergent City.

Drilling down from Smart Cities to the workforce itself, research shows that the introduction of AI will have effects on the profession. The example where an Engineering Technologists is rated at a 75% risk of computerisation while a Civil Engineer on at 2%. Unpacking this research we can see there is a shift in the engineering skills and abilities toolkit away from hard technical math and problem solving skills to soft, science and learning skills – a future toolkit.

The practical application of this is that there will be a reduction in time spent undertaking manual and routine tasks while an increase in time spent focusing on people, solving strategic problems, and thinking creatively.

Future Toolkit

Civil Engineer only

Unique skills with 1.9% probability of computerisation

- Science
- Learning
- Analysis and evaluation
- Negotiation / persuasion
- Management / Leadership
- Social perceptiveness

For engineering specifically, an emphasis needs to be placed on maintaining a classic science foundation while developing enterprise and learning skills. Enterprise to support the non-technical hurdles to service delivery that will be increasingly important and learning skills to embrace new tools and adapt to change. It is these skills that will underpin your agencies adaptability and resilience to a changing future

Finding the right candidates with these skills is a persistent challenge. One made more prescient with the large cohort of current public works professionals approaching retirement. Strategies identified to fill the gap are recognising skill portability and growing the future pipeline of local applicants.

Complimentary skill sets in field such as data science were shown to be effective when applied in multidisciplinary team with engineers. The technical literacy and science fundamentals ensure that problems were interpreted and solved appropriately.

Engaging with the youth to promote the image of public works and provide meaningful work experience through internships lay the foundations for a future workforce pipeline. Public Works provides a unique setting to develop future proof skills with both a wide array of career pathways for diverse experience.

A final x-factor to search for is good learners. With a shifting technology changing the way Public Works operates, staff that can identify and harness the benefits of new technology will set your agency apart.

3. SWOT ANALYSIS SUMMARY

Internal	**Strength** • Connection to community • Infrastructure asset portfolio • Capital delivery • Regulations and policies • Multi-disciplinary workforce • Development of staff	**Weakness** • Fragmented municipalities • Siloed internal structure • Keeping policies up to date • Slow update of infrastructure • Large proportion of workforce nearing retirement
External	**Opportunity** • More time to spend with community and on decision making • Optimisation of service delivery • Decrease in congestion / increase capacity of roads • Reduced road accidents • Increased community mobility • Inter-agency collaboration	**Threat** • Computerisation of tasks • Clandestine technology deployment • Perception as regulatory barrier • Speed of innovation uptake • Inequitable implementation of innovation • Community resistance to change
	Positive	Negative

4. RECOMMENDATIONS SUMMARY

4.1. Transport Disruption

1) Capture, share and search for learnings across professional networks.
2) Engage with providers, demand value and find win wins
3) Provide provision for future shared mobility transport options

4.2. Data, Smart Cities and Industry 4.0

4) Create policies to guide data capture and Smart City development
5) Experiment to build capacity
6) Publish your data

4.3. Public Works and Artificial Intelligence

7) Develop future proof skills
8) Find good learners
9) Recognise portability
10) Grow the pipeline

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5.1. Key Definitions

ADA	American Disability Act
AI	Artificial Intelligence
APWA	American Public Works Association
AV	Autonomous Vehicle
E-scooter	Electric dockless scooter
Geofence	A GPS defined boundary within software
ITS	Intelligent Traffic System
Ordinance	Local Laws
PWX	APWA Public Works Expo
Right of way	Road reserve
Sidewalk	Footpath
TOC	Traffic Operation Centre
UDP	Urban Data Pioneers program and City of Tulsa

6. BACKGROUND

Will a computer take my job? As a young professional in the public works field the uncertainty about the impacts of Artificial Intelligence (AI) on my future in the profession and industry led me to ask this question. Though the same question has likely been asked since the first computers, as AI in engineering moves beyond proof of concept, the question is changing from not if but when and how.

To understand AI's potential effects looking at where we are now and how we are currently responding to other disruptions is a valuable reflection on adaption and resilience in the sector. Data, Autonomous Vehicle's (AV's), and dockless electric scooters (e-scooters) are already changing the way cities plan and operate.

The threat to Local Government from technological disruption is twofold; to its community; and its workforce. Firstly, as the closest form of government to its citizen's, changes in the community from innovative technology often rest on the shoulders of local government to manage. For example, the so-called e-scooter 'wheelmaggedon' where suppliers have rushed deployment in a race for market share without due regard to community safety or social licence leading to their declaration as a public nuisance in San Francisco.

Secondly, innovations that change the way work is conducted also pose a risk to the Agencies' large workforces. Industry 4.0, Smart Cities, Big Data are all iterations to describe how work in these organisations will change.

On this tour disruption in local government was observed in two categories:

- Extra agency transport disruption
    - E-scooters
    - Autonomous Vehicles
- Intra agency work transformation
    - Industry 4.0
    - Artificial Intelligence

Through this tour I have gathered observations on how agencies were preparing or adapting to these changes. To breakdown these observations a SWOT analysis is conducted of public works and recommendations provided to position your city and agency for an uncertain future.

6.1. Governmental Framework and Responsibilities

A key difference between the governmental framework between the Australia and the United States is the County system. Counties are an additional layer of administration that can have varied scope and responsibilities. Through the cities visited two broad patterns emerged relating to the provision of Public Works:

- Within capital cities, the City delivered the full breadth of public works while the Counties had fewer responsibilities.
- Infrastructure that serviced multiple geographical location was operated by a County – e.g. Regional water production, arterial roads.

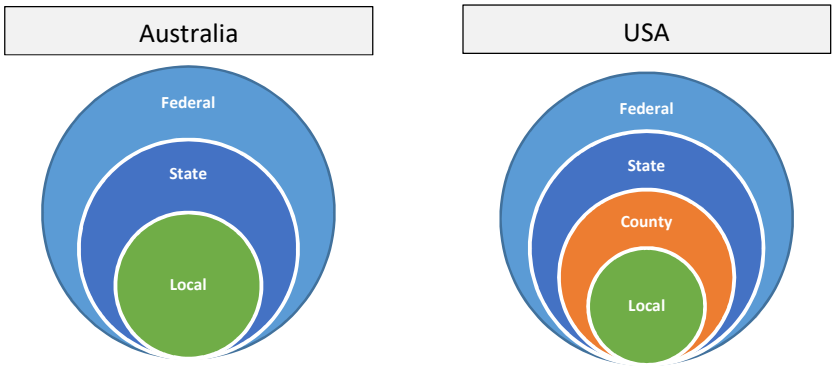

Figure 1 - Government Framework

Local government is charged with a wider range of services than here with the addition of Emergency Services. The public works agencies themselves also typically included water supply and waste water treatment.

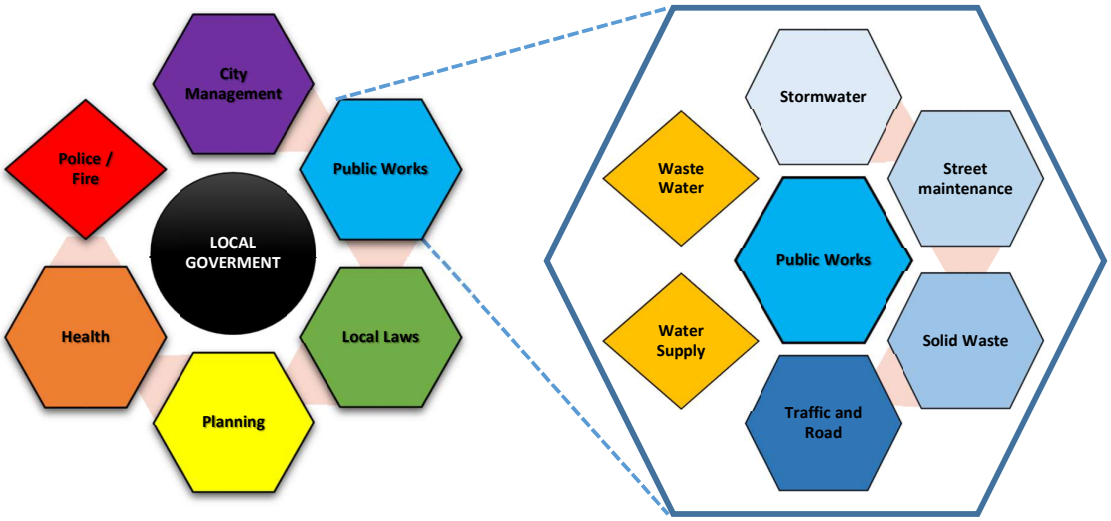

Figure 2 - Government Framework

The wider role of local government meant that in the capital cities almost everything within and underneath the Right of Way or road reserve, was administered by the City. A strong contrast to the fragmented mosaic asset ownership within the road reserve here in Australia. This provided local government and the public works departments with a clear sense of purpose and the remit to realise that purpose.

7. TRANSPORT DISRUPTION

Innovation in the transport space was a feature of the tour with two examples, dockless electric scooters and autonomous vehicles. These services offers tremendous long-term benefits to local government's as transport managers however the current emergent innovation ecosystem is raising short- and medium-term challenges by pushing current regulatory constraints and questioning what is the right mix of infrastructure within the right of way for the long term.

With the safety regulation of vehicles occurring at the federal level the push to market for AVs has been carefully managed by providers to ensure compliance with legal regulations. Trials of AVs were common to demonstrate the technology and benefits to the public. A great example of these companies working within regulatory frameworks through local government to access communities.

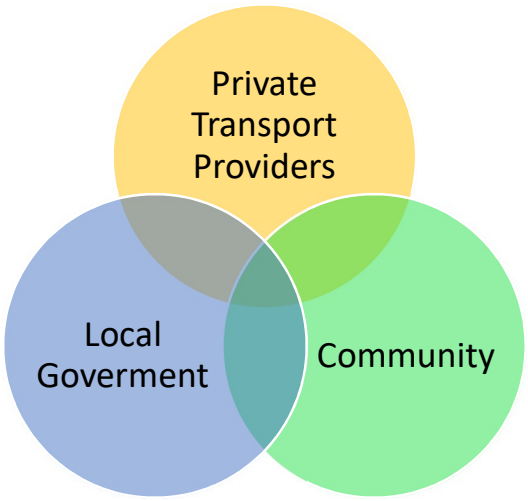

Figure 2 - Project Stakeholders

E-scooters on the other hand were not as well defined within existing regulations and providers have exploited this grey area in a rush to secure market share by going direct to communities without working with Local Government. This has had a negative impact to public space in some cities and highlighted how the roll out of transport technology poses social and engineering questions.

> ***"As brilliant as Silicon Valley is when they think of all these really cool tools to solve the world's problems, the reality is they don't actually know what it takes to build, design, manage, and operate a city the way you do. They need you at the table to have the conversation about what that future looks like."***
> ***(Hand & Waldron, 2018)***

As city administrators and representatives of our communities, we are uniquely positions to support the rollout of disruptive technology to make sure that we are capturing the benefits and reducing the obstacles.

7.1. Dockless Electric Scooters

Key points:

Benefits	Challenges	Disrupts
• Increased community mobility and connectivity • Door to door transport • Reduced reliance on cars • Shared transport data	• Safety • Nuisance / social licence • Equity of access • Fast / clandestine rollout • Adapting existing infrastructure	• Cities transport mix • Allocation of road, footpath and parking space • Transport legislation and planning

Dockless electric scooters are a last mile transport service that emerged in 2018. A user opens a smartphone app, locates the nearest available scooter, scans a code on the scooter and activates it via the app. During the tour we utilised Lime and Bird providers where it cost around $1 to unlock and 15c a minute to ride. They can travel at speed of up to 15mph (24km/h) for a range of 20 miles (32km).

Central to their value proposition is the convenience factor. Without specific locations that they must be docked it is door to door transport option and a replacement for walking. Being electrically powered there is a very low barrier of entry, few restrictions for appropriate clothing and no physical exertion.

A key point of difference to the unsuccessful dockless oBike experience here in Melbourne[1] is that they need to regularly be recharged which offers the opportunity to curate their distribution across a city. In Oklahoma we observed the scooters were collected from outer lying locations and re-deployed in the CBD overnight.

During our stay over a holiday long weekend in Oklahoma, we utilised this transport method to explore points of interest all around the CBD and the miles of shared path networks that extend out of the CBD and along the Oklahoma River. All without raising a sweat and enjoying a high fun factor.

Figure 3 - Daniel and Les exploring Oklahoma on e-scooters

[1] (ABC, 2018) oBike to leave Melbourne after crackdown on bicycle share company https://www.abc.net.au/news/2018-06-12/obike-dockless-bicycle-scheme-to-leave-melbourne/9860314

For public works the challenge is that the current infrastructure within the road reserve has not been designed for this transport method in these volumes. Pressure points in this respect are safety and nuisance. These pressure points have been aggravated by competition where each supplier has a commercial imperative to quickly deploy their e-scooters and secure market share. This has led to the poor outcomes experienced in San Francisco described as a 'Wheelmageddon'[2] and culminating in the City Attorney deeming them a 'public nuisance' and directing them to 'immediately cease unlawful conduct'.[3]

Concerns around e-scooters fall into two broad themes:

- Safety – Injury, accidents and collisions
- Nuisance - Saturation in streets, obstructing footpaths and buildings

During the tour City of Austin were undertaking a study in collaboration with Austin Public Health and the Centers for Disease Control and Prevention (CDC) which have snice been released[4]. The study contacted over 600 patients in a three month period between September and November 2018. During this period there were over 1 million scooter trips and an injury rate of 20 individual injuries per 10,000 trips.

Findings include:

- The perception that most e -scooter riders are injured because of collisions with motorized vehicles was not support by the evidence with only 10% of rider injuries resulting from a collision with a motor vehicle.
- Another perception that excessive e-scooter speed contributes to injuries may be true. More than one-third (37%) of injured riders reported that excessive e-scooter speed contributed to their injury.
- A key finding is a third of the riders were injured during their first e-scooter ride and overall 63% of the injured riders had ridden an e-scooter nine times or fewer before injury.

These findings indicate that largest risk factor is the riders level of experience and that the perceived risks of speed and mixing with motorized vehicles are not as significant.

The downside in door to door dockless mobility is that they can be left at those doors and on the sidewalk leading to nuisance. Possible solutions to this consequence lie with local government, provides, and riders themselves:

- Local government – limiting the total number of suppliers was an important mechanism to prevent saturation in streets while infrastructure can be retrofitted or created to provide designated parking areas. Public information campaigns to raise awareness and maturity.
- Suppliers – technological solutions assisted by; having geofenced parking and riding locations; requiring users to take photos of parked scooters at the end of trips; in app training during sign up.
- Scooter uses – ensuring that scooters are parked appropriately after a ride and reporting incorrectly parked scooters.

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[2] (Kosoff, 2018) *It's Wheelmageddon": San Francisco Is Being Overrun by Venture-Backed Scooters*. Retrieved from Vanity Fair https://www.vanityfair.com/news/2018/04/its-wheelmageddon-san-francisco-is-being-overrun-by-venture-backed-scooters

[3] (ARS Technica, 2018) *San Francisco to scooter startups: Your customers are terrible*. Retrieved from ARS Technica: https://arstechnica.com/tech-policy/2018/04/san-francisco-dubs-new-electric-scooter-startups-a-public-nuisance/

[4] (Austin Public Health, 2019) Austin Public Health. (2019, May 2). *Dockless Electric Scooter - Related Injuries Study.* Retrieved from City of Austin: https://austintexas.gov/sites/default/files/files/Health/Web_Dockless_Electric_Scooter-Related_Injury_Study_final_version_EDSU_5.14.19.pdf

City of Austin have taken it further and also provide information on potential riders too.

Figure 4 - Dockless Etiquette (City of Austin, 2018)

With further guidance from Local Government safety and nuisance issues are likely to reduce as rider and provider maturity increases over time.

Are e-scooters a viable option in the transport mix of a modern and future city? After using them I can confidently say yes. They sit in a niche of last mile transport options and are a direct competitor to walking. In our experience when traversing a city and wanting to either take a short trip over a few blocks or explore an area with no car access, they fit the niche in terms of cost, accessibility and convenience. The City of Austin Dockless Mobility Community Survey Report confirms our experience with respondents rating; comfort and manoeuvrability of scooter; pricing; and use through a smartphone app as favourable features. Furthermore, at the time of writing the current statistics from the City of Austin Shared Micromobility Dashboard for e-scooters is:

Figure 5 - All time e-scooter data[5]

This growing data confirms that e-scooters are a well-supported mode of transport for work, recreation, and entertainment trips – particularly when travelling around one mile.

The next consideration is that if they are going to be included in a cities transport mix, how much space is allocated for them. The broad discourse at PWX18 was that the rise of AVs over the next two decades will lend itself to road diets releasing more space within the right of way. Space for parking scooters on the sidewalk is a priority but so is also providing more protected bike lanes, paved urban trails, painted bike lanes[6].

7.1.1. Getting Implementation Right

When cities were given the opportunity to prepare they would consider the following:

- Engage with transport providers
- Ordinances to control

[5] (City of Austin, 2019), http://transportation.austintexas.io/micromobility-data/
[6] (City of Austin, 2018) City of Austin Dockless Mobility Community Survey Report

- the numbers of scooters deployed by each provider
- use on the sidewalk / footpath
- where they can or can't be parked
- Equity of access. Ensuring that access to the scooters was not limited to areas of high profitability and also deployed in areas of need.

- Requiring something in return – provide their trip data or investment in infrastructure such as bike lanes.
- Developing guidance or training for e-scooter users.

The importance of professional networks was highlighted by Jason Waldron at the City of Kansas. To deliver the Kansas City Street Car and prepare for e-scooters industry and APWA networks allowed him to tap into extensive knowledge and experience to incorporate at Kansas.

7.2. Autonomous Vehicles

Key points:

Benefits	Challenges	Disrupted
• Increased community mobility and connectivity • Decrease congestion / increase in capacity of existing infrastructure • Increased safety	• Community resistance to change • Speed of deployment • Equity of access	• Transport legislation and planning • Cities transport mix • Allocation of road and parking space • Car ownership paradigm

Autonomous vehicles and their iterations are an evolution of technology integration into vehicles that with the recent advancements in sensors, processing, connectivity and systems are now capable of driving in a variety of environments without input from a driver. The Society of Automotive Engineers' levels for automated driving systems shows this evolution:

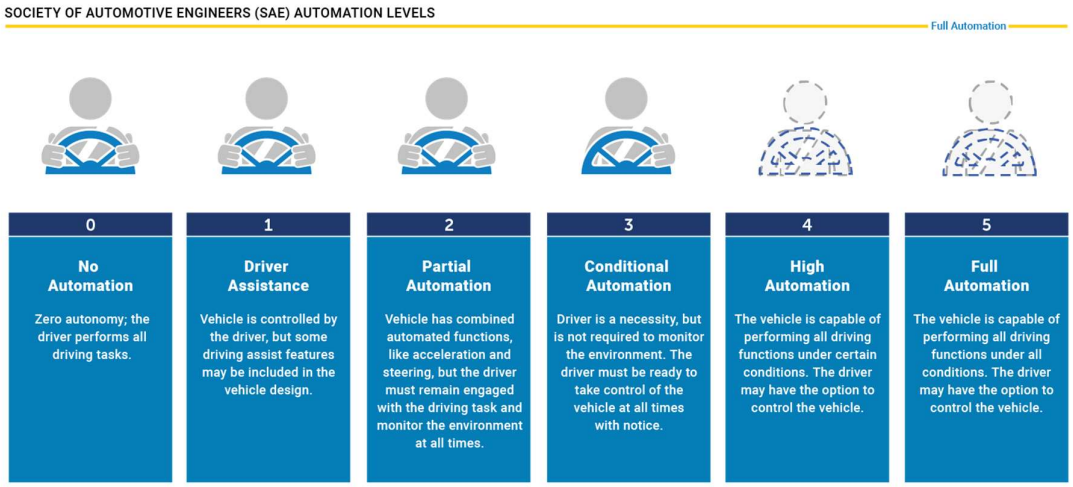


Figure 6 - SAE Levels of Automation (SAE, 2018)

There are commercially available cars with Level 3 and ongoing trials of Level 4. Legal, regulatory and some technical boundaries need to be overcome before we see Level 4 and 5 become widely

available. Through the prism of disruption the primary barriers don't lie in technology, but in legal, regulatory and community attitude constraints.

Autonomous vehicles were a feature of a number of municipalities on the tour with EasyMile (2018) trials planned, underway, or completed. Similar trials have also been completed around Australia. Often these trials include a local flavour such as in Edmonton where the question of how the electric vehicles and their batteries operated in the extreme cold was being investigated (Edmonton, 2018). However, a common thread for these trails was the operation of the EAV shuttle was limited to specific areas with no other traffic present. In this sense they operated in a similar manner to the single track autonomous light rail vehicles servicing the Vancouver and Dallas Fort Worth airports.

The technology incorporated into the EAV shuttles is capable of Level 4 operation, however the regulatory constraints limited the scope of these trails. In this sense the trails are not capability based but instead sought to raise community awareness, build social licence, and community acceptance. This gap is a space for local government to show leadership.

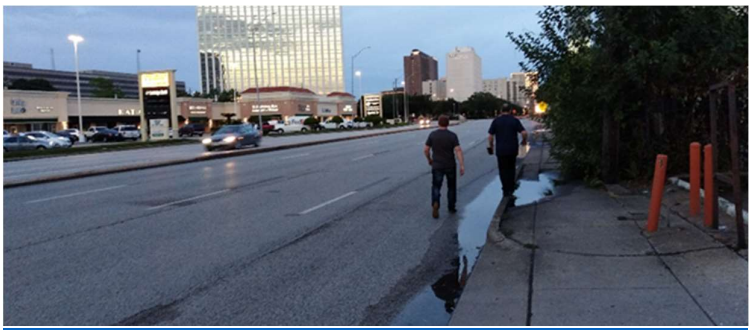


Figure 7 - Cars dominate in Texas

This photo I took in Texas shows the current dominance of the car for in the current transport mix – 8 lanes for traffic and hazardous footpath for pedestrians. Houston is also noted to have 30 car parks per vehicle. In this context you can see the immense potential benefit from AVs in unlocking land within both the right of way and currently used for parking.

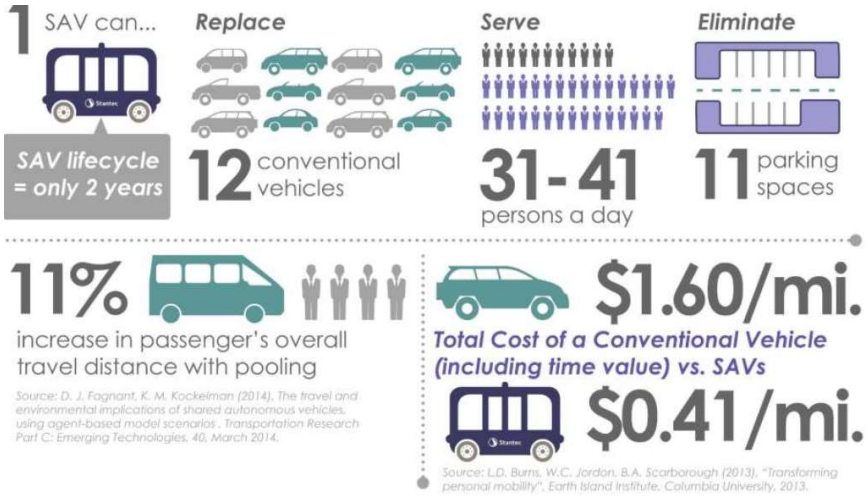


Figure 8 - Benefits of SAVs (Field, 2018)

There are real challenges in how this change will occur that public works will face as AVs rollout. Interestingly, an initial drawbacks could include increased congestion as empty cars can be sent on errands to avoid parking fee. But the benefits are also huge – 100% increase in current lane capacity as an example.

7.2.1. City of Frisco and DriveAI

The City of Frisco had a different AV pilot program in action through a partnership with drive.ai. A key enabler for this program to proceed was the legal framework in Texas that places the liability of a car accident on the owner of the vehicle and not the operator – or lack thereof.

Figure 9 - drive.ai vehicle

Two vehicles operated within a geofenced area on a predetermined route to make pick-ups from an office park and drop offs at a nearby hospitality precinct. Though the trip was only around a mile the team identified that there were perceived barriers for worker in the officers to make the trip. One identified was that a worker might lose their preferred car space if they drove themselves at lunch time.

The user experience was comparable with an Uber where you open a mobile phone app, request a car and nominate your destination, wait for it to arrive at a designated drop point, get in and proceed to your destination. One point of difference with the drive.ai cars is their interactivity with road users around them. A number of LED screens communicate what the vehicle is doing for example waiting for pedestrian to cross the road or picking up passengers.

On the cars there is a complex array of sensors including LIDAR and video collecting and analysing data in real-time. Periodically, the vehicles also interpret the collected data and feed it into a machine learning AI algorithm. Two lessons learnt by the AI during this trail were what to do when a parked car protrude out of their space and into the traffic lane and, what ducks look like. When the vehicles identified both obstacles it stopped and awaited human intervention. The potential with the AI is that once this has been uploaded all other drive.ai vehicles will have the same learning.

7.3. Transport Disruption Recommendations

1) Capture, share and search for learnings across professional networks.

Disruption is inevitable and accelerating in pace. Industry association such as APWA and IPWEA will be a critical conduit to disperse learnings across fragmented municipalities. Reaching out and connecting with these networks will keep your agency up to date.

2) Engage with providers, demand value and find win wins

Working with providers to manage implementation of transport servicers in a way that is sensitive to your local context. Require something in return such as trip data and seek to address equity of access so that the benefits of mobility are shared throughout the community.

3) Plan and provide for future shared mobility transport options.

The challenge for local government is to be adaptive with transport planning to be able to respond to changes as they arise. Suddenly, 30 year transport strategies may need to be updated every 5 years or less. This planning must be kept relevant to ensure that the investment is not wasted. Assets that are being built now will be used by fully autonomous vehicles and other shared mobility possibilities. The time to plan and provide for them is now.

8. DATA, SMART CITIES, AND INDUSTRY 4.0

Key points:

Benefits	Challenges	Disrupted
• Improved decision making • Improved citizen experience	• Community expectation • Multi-discipline • Capital investment	• Technical roles

We are experiencing the fourth industrial revolution. Different to the previous industrial revolutions of steam, mass production, and computers the fourth is not a leap forward in technology but instead the creation of networks to connect information together.

Through Industry 4.0 our understanding of cities is changing. The legacy paradigm is a snapshot view of a city where we obtain data at a specific point in time. A road atlas is good example, each year a complete road atlas is printed that provides up to date information on roads at that specific point in time.

The new paradigm is having live data to build situational awareness and a real time model of a city. Instead of a road atlas you might use Google Maps. It takes road atlas data, overlays congestion data, and plans the most efficient route. If an accident occurs causing congestion and delay on that route, it will offer the option to re-route and avoid it. Suddenly, the understanding of the road network has moved from a static annually updated road atlas, to a real time and adaptive model.

Another important distinction is that the citizen experience changes from one of rigid administration to unique and individual focused services.

8.1. Smart City Architecture

There are a few components that work together to produce the data to power a smart city. This system architecture generally has the following components:

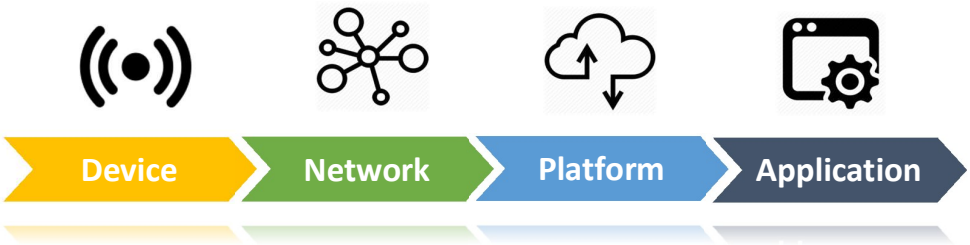


Figure 10 - Smart City System Architecture

This architecture is ubiquitous in the devices that we use every day. An example would be your phone device, connecting through the cellular network, to an email server platform, that lets you read your emails through an app.

It is not only a means to move data but also forms a value chain that creates more value as it progresses further along and spikes at the application stage where analytics can be applied. The

value chain is also not necessarily linear with multiple uses for the same data possible, creating even more value.

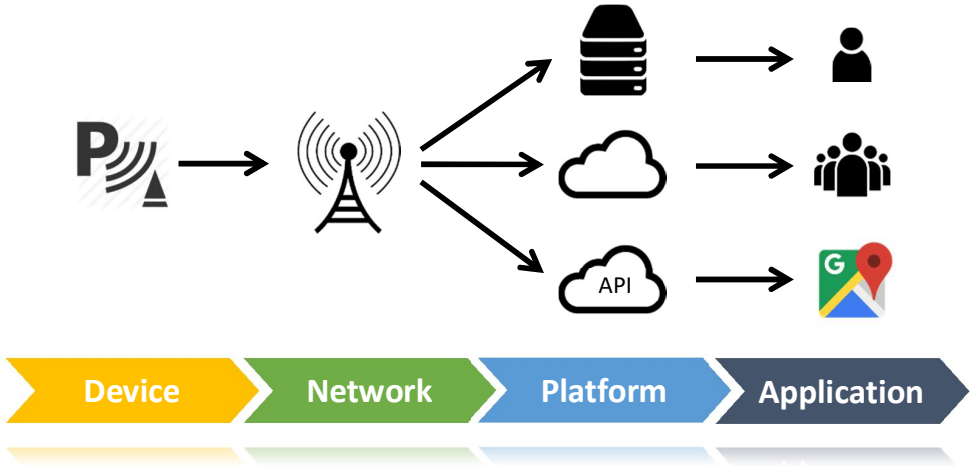


Figure 11 - Multiple data value *chains*

Take the example of a parking sensor. It connects across a wireless network and can provide info to be used in a number of different ways:

- Collecting data from the parking sensors, storing it in your computer and analysing it. This will give us good data on utilisation that will help us to assess if we are meeting community needs.
- We can also provide this data on public cloud so the community can access the data to see where parking is available and make their own assessments.
- This data could be connected through an API to existing apps like google maps. This would allow real time navigation to connect trips to the closest parking available near their destination where users want to access the information.

The same data has progressing through different platforms and apps can benefit different users.

8.2. Smart City Models

One helpful model that was presented by Ashley Hand of Citifi at PWX, was the following smart city models:

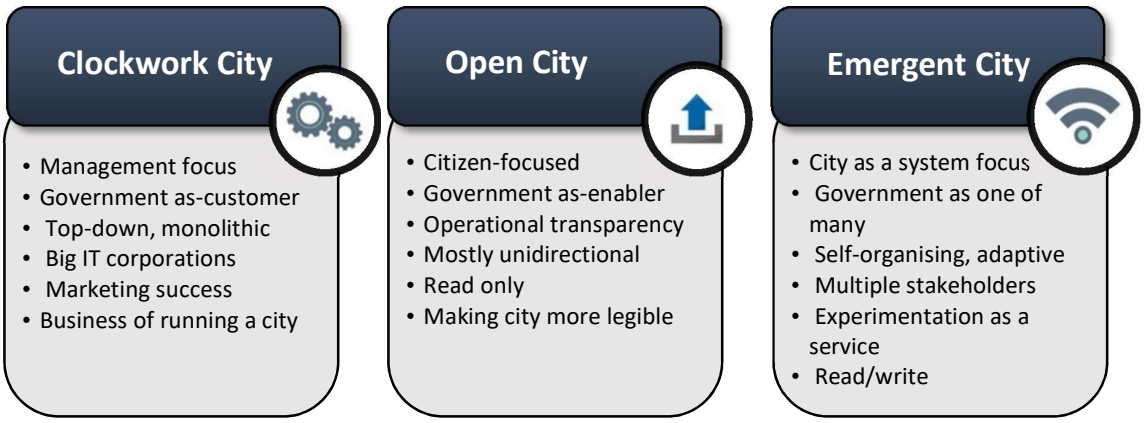


Figure 12 - Smart City Models (Tolva, 2015)

These models are not an evolution but coexist. Agencies and even projects can weave between them.

An example of how these models operate is public transport within a city:

- A Clockwork City - setup, track and optimise bus routes to operate as efficiently as possible.
- An Open City – provide live bus location data to commuters so they can plan when they need to catch it.
- An Emergent City – consider where the trip destination is and connect a commuter to the most efficient transport option be it public or private.

8.3. Smart City Enablers

Throughout the tour themes emerged about the different smart city models and their organisational context. To try and describe them I have added a layer of Smart City Enablers to the models below. Blue items reflect that present within organisations and the orange those from outside.

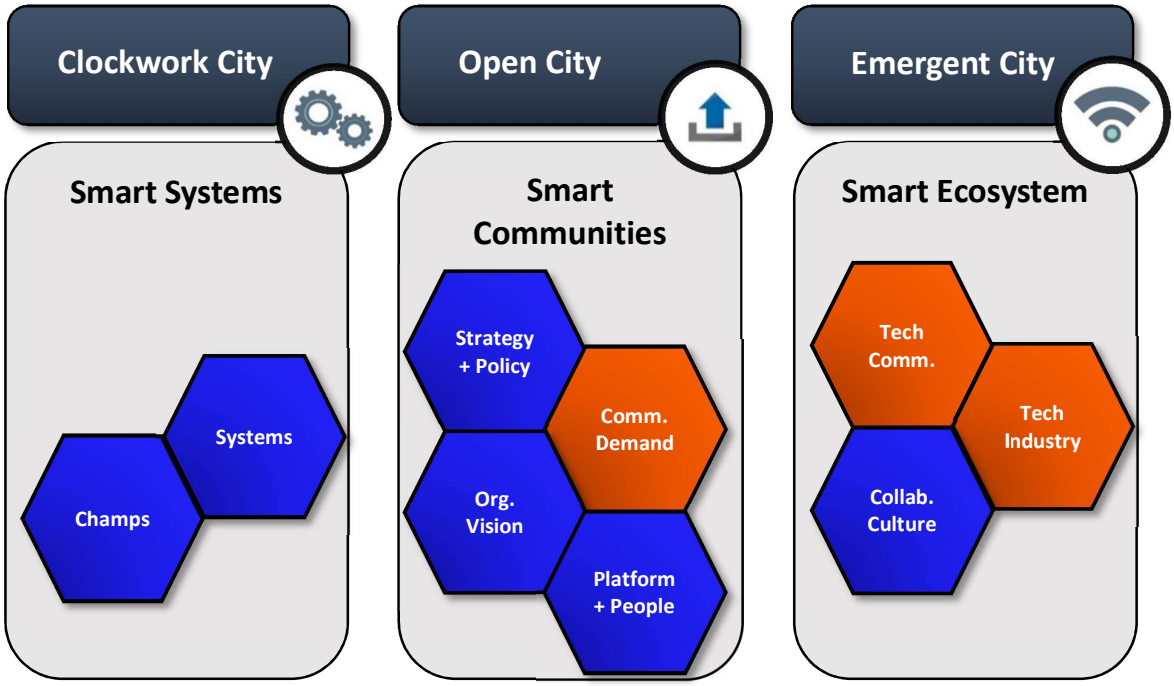


Figure 13 - Smart City Enablers

Clockwork City – Smart Systems. City administration is the core business of local government supported through a hierarchical structure and legislation. This makes the Clockwork City model the natural fit for public works.

- Champions. Within these structures individuals have pushed for a lead innovations within their portfolios.
- Systems. Building beyond individual champions a number of system were used that were both process based such as LEAN or software based like GIS or Python.

Open City – Smart Communities. Open Cities grow from community demand and or an organisational vision. Then supported by strategy, policy and investment in platforms and people created the citizen centric Smart Communities that place operational transparency at the heart of business.

- Organisational Vision. A cultural shift driven by organisation vision to include transparency at the core of its operations.
- Strategy + Policy. The roadmap for realising the vision.
- Platform + People. Investment in systems and personnel.
- Community Demand. An engaged citizenry seeking to consume the data.

Emergent City – Smart Ecosystems. Finally, within tech precincts that supported a tech industry and community, a collaborative agency culture to search for the best overall delivery of a service was the hallmark of a Smart Ecosystem of the Emergent City.

- Technical Industry. The presence of a start-up and technical industry willing to utilise published data.
- Technical Community. Close partnerships with regional universities and engaged citizens.
- Collaborative Culture. The culture within both private and public realms to work together to solve problems.

The City of Edmonton was very active in the Smart City space with a number of initiatives across the different models:

- Champions experimenting with sensors. Using the existing module connectivity to streetlights to provide power, engineering intern students were building their own sensors to count pedestrians through infrared to avoid privacy concerns and collect data on public utilisation of infrastructure.
- Meeting the community demand to consume information where they want. Through their open data portal providing real-time transport information local app developers created an app to track the location of services.
- Not doing the technological heavy lifting by collaborating with the Technical Community. Our agencies have a finite budget, providing data that we already collect for the use of if the good will of the community or existing infrastructure of larger tech companies provides greater benefit to our communities.

8.4. What do you do with Data?

"Accountability builds better services.
Analysis builds new processes.
Open data builds businesses."
(Hand & Waldron, 2018)

The most common and sophisticated data collection systems seen on the tour were related to traffic management. With capital cities managing large arterial road networks and snow ploughs operating in the winter months the preferred traffic light systems included video vehicle detection. These systems operated by having cameras mounted above the intersection that identified approaching cars within each lane. More modern system operating over fibre optic networks could use high definition cameras to increase accuracy. The video feed would then sent back to the Traffic

Operations Centre and be processed by an Intelligent Transportation System, which would control the traffic signal phasing.

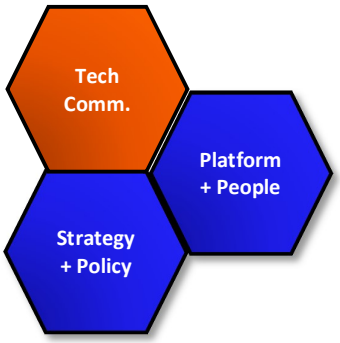
Historically, traffic signal phasing would be set and forget but through these system providing a constant real-time feed of data traffic engineers were able to monitor and adjust the system to respond to changing conditions. At Hennipen County the traffic engineers were optimistic that fully variable signal phasing would be possible in the near future through AI to continually adjust the network to optimum efficiency.

These system were not just used for signalling, the data is also valuable to law enforcement highlighting the need for strategies and policies around the collection and use of data.

8.4.1. Data to build trust

At City of Austin there was a clear view that as a public entity any data created by the organisation was public data and should be readily available to the public. The realising of this vision is their Open Data Portal https://data.austintexas.gov/. Through this portal you can see a wide array of operation and performance datasets across the whole organisation. The datasets available on this portal are extensive and demonstrate their commitment to transparency while increasing accountability.

A unique element is that it also included health data. This could provide the data to run long term evaluations to see the health benefits of Public Works e.g. if constructing a network of shared paths leads to an increase in the health.

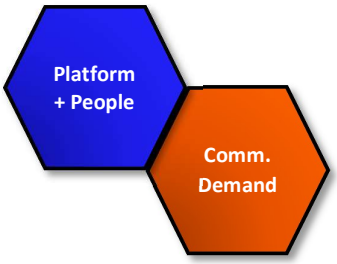


An option available to American local government is to issue bonds to raise funds. A bond issue has to be put to a vote of the citizens and pass with a majority of support. This need for a successful public vote increases the citizen engagement with the projects and the open data platform practical response to provide information on the background, context and updates on the $720 million dollar portfolio of projects.

Navigating on the project tracking tool will show you each projects location, budget and status updated monthly, and a public contact to find out more information. A similar depth of information is available on all categories of the open data portal and it really challenged my sense of what data should be publicly available and replaced it with why shouldn't all data be available.

Figure 14 - City of Austin Open Data Portal

8.4.2. Kansas City Snow Ploughs



Kansas City (KCMO) have a fleet of GPS tracked snow ploughs to clear the roads. The typical benefits organisational benefits associated with the addition of GPS to these vehicles is fleet maintenance, safety, and optimisation. What KCMO found was that when a large snow storm came through, there is considerable community angst about when their street will be ploughed and calls for information.

What KCMO do with that GPS data is live publish the locations of snow ploughs, so that the resident can see that they are active and when their street will be done. This has led a decrease in phone calls and increase in community satisfaction but was not why they initially bought the GPS systems.

This is an example of meeting the consumers of information where they want to be.

8.5. Protect privacy

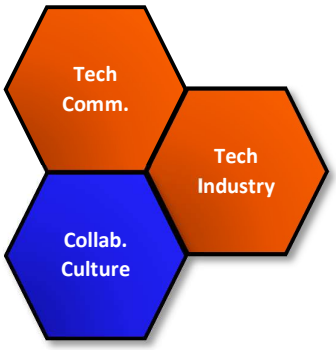
Seemingly innocuous data sets can cam also be used for nefarious purposes, particularly when combined with other data. The New York City Taxi and Limousine Commission released a data set with the details of every taxi trip in 2013 showing where they started and ended. This data set was not adequately anonymised for privacy and by using public available images of celebrities Anthony Tockar (2014) was able to drill down into the data and find out exactly where celebrities travelled to and from in the paparazzi photos.

The balance between open data transparency and protecting individual privacy must be a core and ongoing consideration with data collection and publication. It requires specialist advice but it is not insurmountable. At City of Edmonton in collaboration with EPCOR they published the 2016 water usages so that citizens can compare how their blocks water consumption compared to others. The city was divided up with hexagons and those with more than only city block areas with at least 10 accounts are shown:

Figure 15- EPCOR water usage comparison map (City of Edmonton, 2018)

8.6. Building Capacity

8.6.1. City of Edmonton – Reaching Out



The City of Edmonton and Austin acknowledged that in the public works realms data collection is core business but creating applications is not. City of Edmonton run collaboration programs and competitions for the local app developers and start up scene to take the City's open data and create applications for uses that weren't previously considered.

The City has the sensors, networks, and a platform but that is where the value chain of the data was end. There has been extensive work in the customer service field, but delivery of services has not had the same investment. The high-level approach taken is was that there are not unlimited IT resources within the organisation, using what is available in the community will expand the throughput. The City encourages all individuals, industries and academic sectors to work as partners in our open innovation ecosystem (City of Edmonton, 2018)

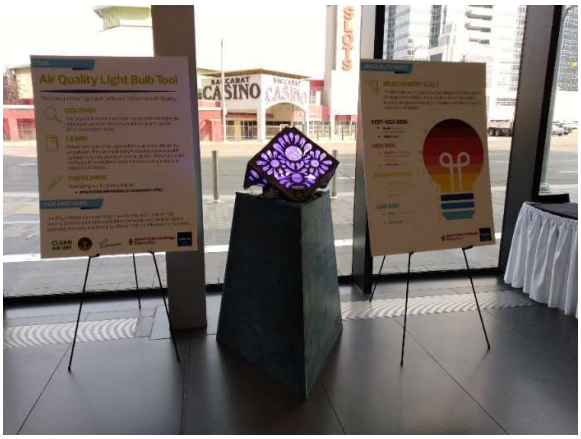
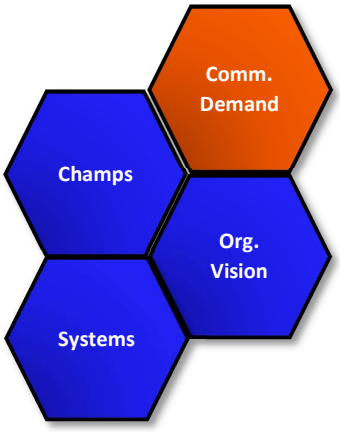


Figure 16 - Air Quality Light Bulb at City of Edmonton

An elegant example of this was an Air Quality Light Bulb pictured above in the foyer of the City of Edmonton's created by a community member. It takes the air quality data published by the City and changes colour based on that data, from blue – low risk to dark red – very high risk. During the tour there were significant wildfires active in the Rocky Mountains and the light bulb had been into the red range. A number of other open data community developed apps were showcased that tracked buses and visualised local law data sets.

8.6.2. Tulsa - Data Pioneers



The state of Oklahoma was unique in our trip in that local government was not funded by a property tax and instead drew income from sales taxes. This posed significant challenges for the oil producing state during the slump in oil prices in the early 1980s and national recession in 2001.

This forced the City of Tulsa to be very lean in their operation and demanding for value. Faced with these challenges in 2016 the newly elected Mayor Bynum turned to data driven decision making. The final hurdle was that his term began in the middle of a financial year so there was no immediate funding available.

"We had no budget, and so we started looking at who is out there who wants to help solve these things and are motivated by wanting to help their community," he said[7]. Urban Data Pioneers (UDP) was his solution.

The program combines City employees and community members that volunteer their time and explore questions through the analysis of data. The blueprint for UDP is as follows (Cities of Service, 2018):

1. Identify a set of problems or issues that the Urban Data Pioneers can examine. These should align with the priorities of the mayor or city chief executive.
2. Design the program, including creating a timeline, identifying data sets, and securing meeting space.
3. Recruit city staff and citizen volunteers. While the city will need to recruit subject matter experts and data analysis experts, not all volunteers need expertise to participate.
4. Launch the program with a kick-off meeting to introduce the program parameters, select projects, and set expectations.
5. Form teams of 10 or fewer participants, including at least one subject matter expert, one data analyst, and one team leader. These teams will be formed at the kick-off meeting based on shared interest in a problem.
6. Work with teams to refine the problem they are examining and scope their projects
7. Provide tools for data analysis and train participants to use them.
8. Present findings from the Urban Data Pioneers teams to city leaders and other city staff.
9. Measure the impact of the program.

[7] Cities of Service. (2018). *Urban Data Pioneers.* Retrieved from Cities of Service: https://citiesofservice.org/resource/urban-data-pioneers-tulsa

10. Celebrate successes and provide feedback to participants.

Through Urban Data Pioneers a model for street reconstruction prioritisation was developed that started with pavement condition index and then overlaid issues like traffic crashes, sidewalk gaps, ADA accessibility, bicycle infrastructure, and storm sewer overflow to create a super priority list. A $500 million capital package will be put to voters in 2019 comprising largely of street repairs determined by this Urban Data Pioneers model.

Bringing teams together from across city departments also allowed people to engage with fellow employees within city hierarchy on the neutral territory of Urban Data Pioneers without any particular department holding sway was a key feature of the program internally contributing to a more collaborative and less siloed culture.

8.7. Data recommendations

4) Create policies to guide data capture and Smart City development

Recognise your agencies wider community and industry context to try and understand the appropriate Smart City models for development. Setting a clear vision and supporting policy are the best steps to ensure that your Agency's development is collectively in the right direction. Before you start investing this North Star showing what you want to accomplish from smart city is important to ensure that resources are not wasted and improve the chances of sustainable success.

5) Experiment to build smart city capacity

Look for opportunities to experiment starting in small scale and increasing from there. This is important to limit the risk for the possibility of failure but also to acknowledge it is not simply technical problems that need solving but an additional cultural change is required. Emulate programs like Urban Data Pioneers that build both internal and community capacity.

6) Publish data

Extend the value chain of your data and capture more benefit by publishing your data. Accountability builds better services, analysis new processes and Open Data builds businesses. The first benefit may be to your own organisation by breaking down previous data sharing silos. A further potential benefits is leveraging community capacity to process data reducing resource requirements within the agency itself.

9. PUBLIC WORKS AND ARTIFICIAL INTELLIGENCE

Benefits	Challenges	Disrupts
• Optimisation of service delivery • More time to spend with community and on decision making	• Computerisation of tasks currently completed by engineers • Finding the right skills	• Workforce

To understand the possible impacts of AI on public works first we need to look at the tasks that makes up the roles themselves. Frey and Osborn (2003) breakdown workplace tasks in their Future of Employment: How Susceptible are Jobs to Computerisation report by using an AI algorithm to analyse 20,000 unique task descriptions across 702 occupations in the United States Department of Labour O*NET system. These occupations made up 97% of US workforce at that time. The AI was taught to assess if data will be available to sufficiently specify each task to be performed by state of the art computer-controlled equipment. And tasks marked subsequently rated as computerisable are not. Using this methodology Frey and Osborn study estimate that 47% of the US workforce is exposed to future automation:

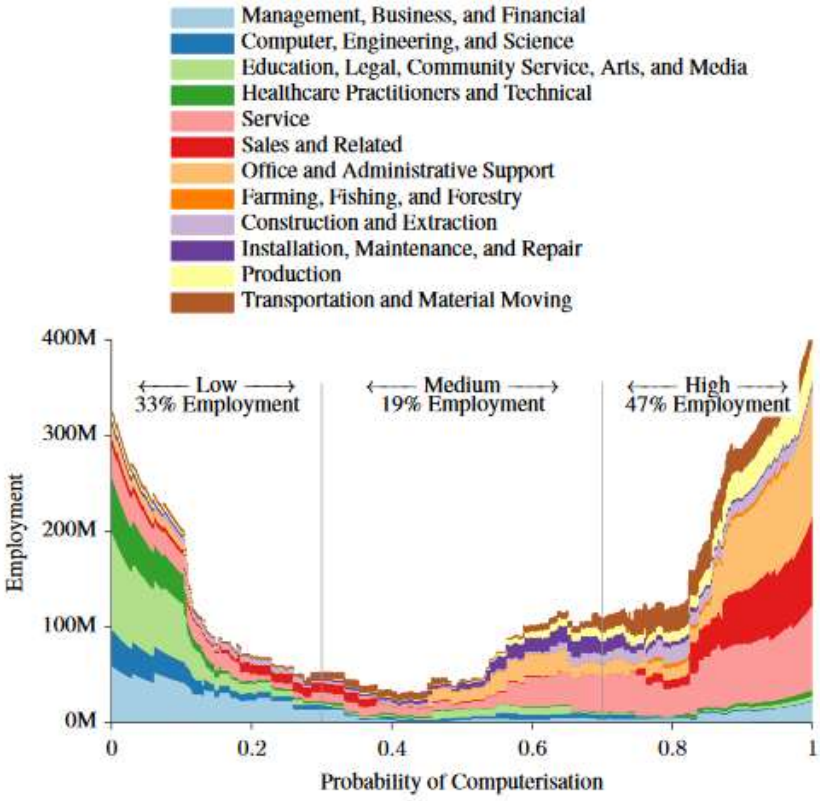


FIGURE III. The distribution of BLS 2010 occupational employment over the probability of computerisation, along with the share in low, medium and high probability categories. Note that the total area under all curves is equal to total US employment.

Figure 17 – Probability of Computerisation in the US Workforce (Frey and Osborn 2013)

Using the same methodology Durrant-Whyte (2015) conducted the analysis on the Australian workforce which has a smaller segment of the service industry lowering the total proportion of jobs at high risk of automation to 40%:

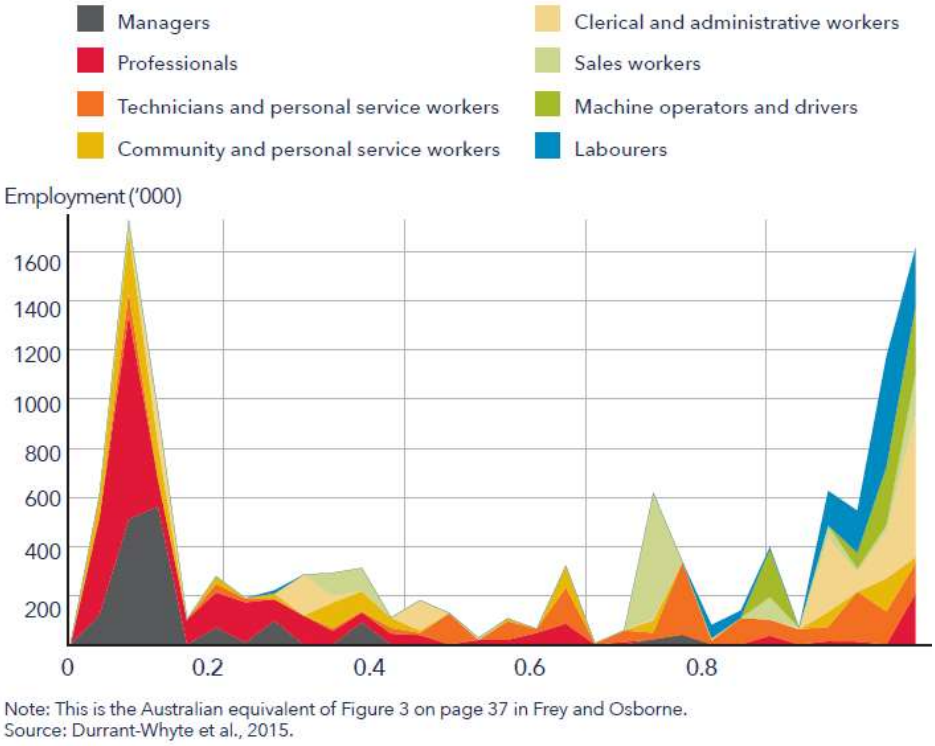


Figure 18 - Distribution of job categories and employment against probability of computerisation in Australia (Durrant-White et al, 2015)

With the growing availability of data sets from Smart Cities, an increasing number of tasks are becoming computerisable within public works. This is consistent with the broader Industry 4.0 effects being felt in other industries such as the law and finance.

Though the numbers appear intimidating not every task was at risk of automation with technical bottlenecks preventing the full computerisation of the workforce. These bottleneck were identified as:

- Perception and manipulation tasks. The perceptiveness to interpret a wide range of data and adaptability a process accordingly is challenging for computers to duplicate.
- Creative intelligence tasks. The originality of creativity and humour are problematic to codify and replicate.
- Social intelligence tasks. Tasks that include negotiation, persuasion, and care that require interpretation and responding to human emotions have proven difficult for computers to simulate.

For public works and engineering the Social intelligence bottlenecks that include negotiation, Persuasion, social perceptiveness is the most relevant. Frey and Osborn predict that while computers are entering the domain of engineering they are strongly complimentary. The

Foundation for Young Australians report mirrors this with a pivot away from routine technical work towards face time:

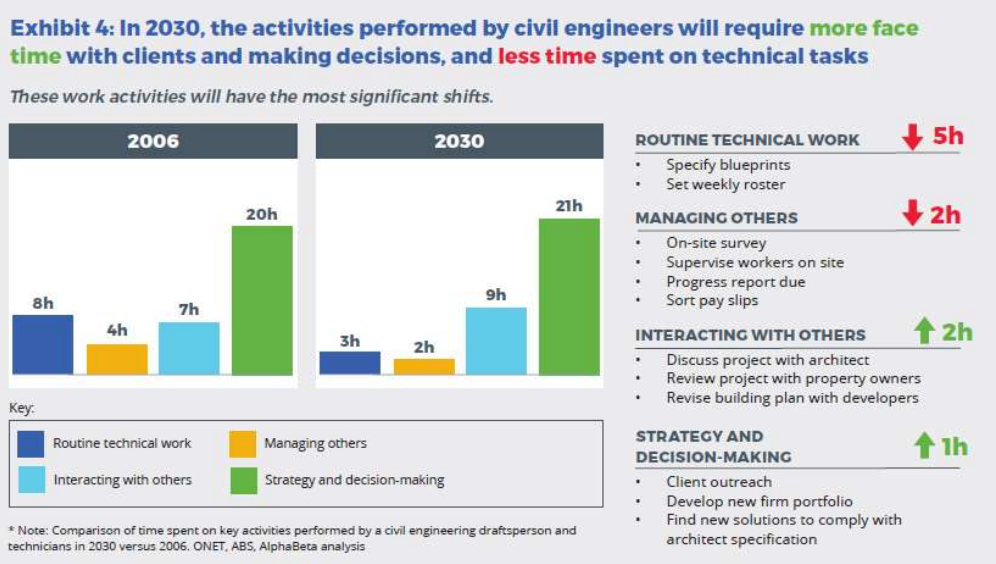


Figure 19 – Excerpt from The New Basics (Foundation for Young Australians, 2016)

To explore this pivot and the change is skill priorities we can drill down into the tasks of the role.

9.1. The changing engineering toolkit

Within the O*NET job catalogue there are discrete job titles for a Civil Engineering Technician and a Civil Engineer. The Future of Employment study assess the probability of computerisation of these roles as 75% for the Technologist and only 2% for the Engineer. This assessment is based on the listed skills, knowledge, and abilities for both these roles. However, while the knowledge and abilities are almost identical, there is a significant gap between the 10 skills for the Technician and 24 for the Engineer. Therefor within these unique skills lies a 73% difference in risk of computerisations and a potential insight into the changing skills sets for a future of engineering with AI - a Future Toolkit.

Legacy Toolkit	Future Toolkit
Civil Technician and Civil Engineer Shared skills with 75% probability of computerisation	**Civil Engineer only** Unique skills with 1.9% probability of computerisation
• Complex problem solving • Critical thinking • Judgement • Maths • Active listening • Reading, speaking, writing	• Science • Learning • Negotiation / persuasion • Management / Leadership • Social perceptiveness • Analysis and evaluation

Figure 20 - Legacy and Future Skill Toolkits

A full comparison of the O*NET job skills, abilities, and knowledge for the two roles is attached in Appendix A.

Throughout the tour a consistent emphasis across Public Works directors and Human Resources executives was the importance of communication skills in their potential candidates. I think that this is an acknowledgement that within the modern public works field barriers to successful delivery of a project lie within the realm of soft skills more than technical skills. Or more simply put we have hard skills to solve problems but can improve the soft skills to aid how we implement them.

9.2. Getting the right mix of skills

Throughout the tour there was a consistent theme of experiencing difficulty in finding enough public works professionals to fill roles. This was further exacerbated when searching for candidates with strong communication skills and digital literacy. Finally, there is also a large cohort of the workforce approaching retirement which is consistent with Australia where the Professionals Australia Professional Engineering Employment and Remuneration Report 2018 (Professionals Australia, 2018) showed 60% respondents were looking to leave or retire from the industry in the next 5 years. At the City of Houston in the Water the Senior Assistant Director of Wastewater Operations, Shannon Dunne reported that 70% of his operators could retire today, in some sections 80%.

Recognising that posting job ads and hoping for positions to be filled was not returning the required results, Agencies were looking to expand their applicant pool by:

- Recognising skill portability
- Growing the future pipeline of local applicants

During our meeting with City of Minneapolis we discussed the application of smart city data. Having the right data management / data scientist element was required to ask the right question of the data sets – something traditionally outside the engineers' toolkit. However, the traditional engineering skill set was seen as important to provide a classical applied science approach to understanding and solving problems.

In achieving this the City of Minneapolis built a team with both data specialists with high digital literacy and engineers with lower digital literacy working together. This is a model that acknowledges the portability of a data scientist skillset into the public works portfolio in using the growing volume of data sets to support decision making while keeping a classical science approach

to ensure that the right questions are being asked and appropriate answers. In my opinion this is the same model that we will see in the future with engineers working alongside AI – each complimenting the other.

"Bringing in new technology does not replace the responsibility of Engineers. The role of engineers within Houston Wastewater is slowly changing to optimisation."
Shannon Dunne, City of Houston

9.3 Developing the pipeline of future skills

Public works is a significant employer in North America. The wider breadth of services delivery compared to Australia give the sector more clout when competing for potential candidates but also for promoting public works to future candidates. A key point of difference for public works is the breadth of roles available and different pathways to develop within it.

Programs to connect school and university students to opportunities to gain experience in public works were a fantastic feature of the trip:

Figure 21 - Public works engagement programs

Starting with more informal programs like bring your kids to work day and Hennipen County where kids were shown all the equipment utilised by public works departments.

City of Houston initiated Grow Your Own Work Workforce[8] to plant the seed in the minds of students that there are a wide array of opportunities available in local government. Departments within the city offer internships and co-op opportunities, guest speakers, tours, adopt-a-school programs and a presence at the Find Your Path Career Day Expo. Their objective is to get students to consider, prepare for, and even experience a job within the City and create a pipeline of future candidates.

One part of this initiative is the Hire Houston Youth[9] program where 16-24 year olds apply for summer jobs across a number of participating employers. Step Up[10] was another at City of Minneapolis for 14-21 year olds providing paid internships. The focus on these programs was providing meaningful work experiences to the participants but to also diversify the workforce of the businesses.

Once at university internships were common opportunity extended by public works agencies and intakes of around 50 were common through programs like City of Houston's Pathways[11]. Young engineers were coming out of university competent in engineering but public works is much broader than that alone. Currently, universities focused on technical skills and relying on the companies that

[8] (City of Houston, 2018) Grow Your Own Workforce. http://www.houstontx.gov/hr/gyow.html
[9] (Hire Houston Youth, 2019) Hire Houston Youth. https://hirehoustonyouth.org/
[10] (City of Minneapolis, 2019) Step up http://www.minneapolismn.gov/cped/metp/step-up_home
[11] (City of Houston, 2019) Pathways http://www.houstontx.gov/hr/gyow/pthwys_prgrm.html

hire them to develop the soft skills. Very important that public works engineers close the loop back with universities.

"How do you teach Engineer's to do the political dance and develop political acumen?"
David Browne, City of McKinney

At the City of Frisco this soft skill development was enabled by a strong culture of trust and on the job experience. By sending developing staff out to address issues with home owners associations that often prove to be difficult stakeholders, they were given the opportunity develop these skills. The trusting down to staff is captured by a simple test with the Director of Engineering Services:

"Is it the truth; is it fair; can you stand up in a public meeting and explain why?"
Paul Knipple, City of Frisco

Once attracting staff the final challenge was keeping them. Providing a roadmap to new staff was also highlighted by Hennipen County so that new started could understand the careers paths available to them. David Brown Public Works Director City of McKinney found that (PWX Directors meeting) young engineers were leaving after 3-5 years because they couldn't see a future and they had to move up or move out. The challenge was to show them the options for coaching and career development while the best way was giving them the ability to cross train within the organisation. Letting them go to another area the get exposure and provide diversity was important to maintain engagement.

9.4 The X Factor

I did identify one trait that was present within all the exceptional multi-disciplinary public works professionals that pushed themselves outside the pure engineering space. It is also one that was not on the radar when speaking with agencies HR divisions. Susan Ancel the Director of Stormwater Strategies at EPCOR in Edmonton was the first to define this trait at the start of our tour – curiosity.

Curiosity is also captured in the Future Toolkit as skills of learning:

- Active Learning — Understanding the implications of new information for both current and future problem-solving and decision-making.
- Learning Strategies — Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.

To seek out, understand the application, and learn how to harness new technology will be even more important as the pace of innovation increases. It is these skills that will underpin you agencies adaptability and resilience to a changing future.

9.5 Recommendations to Prepare for the Future of Work

7) Develop future proof skills

Social intelligence skills are a current bottleneck for AI which also overlaps with a well-established recruitment focus throughout the industry strong soft skills set. The next emphasis needs to be placed on maintaining a classic science foundation while developing learning skills. Science foundations to work understand problems and ask the right questions while learning skills to embrace new tools and adapt to change. It is these skills that will underpin your agencies adaptability and resilience to a changing future.

8) Find good learners

The pace of change will accelerate and staff with a high degree of curiosity that can harness new technologies will be indispensable.

9) Recognise portability

Consider a breadth of candidates with similar skill sets when recruiting for positions, not just candidates within an occupation. Similar to Engineers working complimentarily with AI, other skills sets such as coding and data science offer a strong value proposition within the Public Works portfolio.

10) Grow the pipeline

Engaging with the youth to promote the image of public works and provide work experience through summer jobs and internships creates a pipeline for growing your future workforce. Once within your organisation ensure professional development is fostered to retain engagement with opportunities to gain diverse experience.

10. CONCLUSION

Innovative technology will continue to change Public Works, cities and their communities. The speed of this change will test the resilience of Agencies and their workforces.

Through the lens of transport disruption a network of fragmented municipalities with siloed internal structures will find difficulty in keeping their transportation policies and infrastructure mix up to date with shifting community expectation and competitive private transport providers. The benefit of these transport options are immense in increasing mobility, reducing road accidents, and releasing land for other uses. Technical barriers to achieve this are being overcome at a faster rate than the regulatory and community barriers. Public Works is uniquely placed to manage this change by controlling regulations, updating physical infrastructure, providing leadership for the community.

Knowing its communities and how to administer a city is core business for Public Works. Engaging with private transport providers to find mutual benefit in increasing community mobility while managing nuisance and safety issues for their city is a successful formula. Collaborating with these providers but also across agencies to share learnings and successes is the core of this formula. Consequently, the skill set to deliver places a high importance on social intelligence and digital skills.

Smart Cities will usher in Industry 4.0 by providing real-time data to improve decision making and optimise service delivery. Interacting with this data requires a digital skill set beyond that traditionally included in Public Works, nevertheless a foundation of classical Engineering science ensures the right questions are asked of the data and an understanding of the impacts of outputs.

The push for Open Data allows this communication to flow outside an Agency and empower technically literate communities. This has the potential to take advantage of capacity and specialist skills outside the organisation and increase the value chains produced by that data. A surprising benefit is that it also allows that data to flow to other areas within the Agency themselves. As the volume of datasets grows so does the sophistication in which privacy and security have to be managed, which requires more investment.

The path to becoming a Smart City is supported by understanding your agency's enabling attributes and surrounding context. To start the journey develop capacity through experimentation and quick wins. Programs like City of Tulsa's Data Pioneers extend the capacity building into the community, helping generate new ideas and growing demand for Open Data. Setting a clear vision and supporting policy are the best steps to ensure that your Agency's development is collectively in the right direction.

The trade-off for data led decision making is that it accelerates the computerisation of work. If a problem can be specified and there is an applicable dataset it is likely that it will be completed by a computer in the future. As a result, the future role of Engineers complimented by AI will pivot away from technical routine work and towards social intelligence tasks.

Strategies for attracting these new skills sets and replenishing a retiring workforce include recognising the portability of skills and growing the pipeline of future candidates. Public Works provides a unique setting to develop future proof skills with both a wide array of career pathways for diverse experience and an emphasis on public service over profit. The challenge is promoting these benefits and programs to provide experience to kids and young adults is a terrific way to do just that.

A final x-factor to search for is good learners. With a shifting technology changing the way Public Works operates, staff that can identify and harness the benefits of new technology will set your agency apart.

10.1. SWOT Analysis

	Positive	Negative
Internal	**Strength** • Connection to community • Infrastructure asset portfolio • Capital delivery • Regulations and policies • Multi-disciplinary workforce • Development of staff	**Weakness** • Fragmented municipalities • Siloed internal structure • Keeping policies up to date • Slow update of infrastructure • Large proportion of workforce nearing retirement
External	**Opportunity** • More time to spend with community and on decision making • Optimisation of service delivery • Decrease in congestion / increase capacity of roads • Reduced road accidents • Increased community mobility • Inter-agency collaboration	**Threat** • Computerisation of tasks • Clandestine technology deployment • Perception as regulatory barrier • Speed of innovation uptake • Inequitable implementation of innovation • Community resistance to change

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12. APPENDIX

12.1. Appendix A

Information sourced from United States Department of Labour O*NET Online: https://www.onetonline.org/

17-3022.00 - Civil Engineering Technicians

Apply theory and principles of civil engineering in planning, designing, and overseeing construction and maintenance of structures and facilities under the direction of engineering staff or physical scientists

17-2051.00 - Civil Engineers

Perform engineering duties in planning, designing, and overseeing construction and maintenance of building structures, and facilities, such as roads, railroads, airports, bridges, harbors, channels, dams, irrigation projects, pipelines, power plants, and water and sewage systems.

Knowledge Comparison	Engineering Technician	Civil Engineer
Administration and Management — Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modelling, leadership technique, production methods, and coordination of people and resources.	✓	✓
Building and Construction — Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.	✓	✓
Clerical — Knowledge of administrative and clerical procedures and systems such as word processing, managing files and records, stenography and transcription, designing forms, and other office procedures and terminology.	✓	✘
Computers and Electronics — Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.	✓	✓
Customer and Personal Service — Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.	✓	✓
Design — Knowledge of design techniques, tools, and principals involved in production of precision technical plans, blueprints, drawings, and models.	✓	✓
Education and Training — Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.	✓	✓
Engineering and Technology — Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.	✓	✓
English Language — Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.	✓	✓
Mathematics — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.	✓	✓
Mechanical — Knowledge of machines and tools, including their designs, uses, repair, and maintenance.	✓	✓
Physics — Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub- atomic structures and processes.	✓	✓
Public Safety and Security — Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.	✓	✓
Transportation — Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits.	✓	✓

Abilities Comparison	Engineering Technician	Civil Engineer
Category Flexibility — The ability to generate or use different sets of rules for combining or grouping things in different ways.	✓	✓
Deductive Reasoning — The ability to apply general rules to specific problems to produce answers that make sense.	✓	✓
Far Vision — The ability to see details at a distance.	✓	✓
Flexibility of Closure — The ability to identify or detect a known pattern (a figure, object, word, or sound) that is hidden in other distracting material.	✓	✓
Fluency of Ideas — The ability to come up with a number of ideas about a topic (the number of ideas is important, not their quality, correctness, or creativity).	✓	✓
Inductive Reasoning — The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).	✓	✓
Information Ordering — The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).	✓	✓
Mathematical Reasoning — The ability to choose the right mathematical methods or formulas to solve a problem.	✓	✓
Near Vision — The ability to see details at close range (within a few feet of the observer).	✓	✓
Number Facility — The ability to add, subtract, multiply, or divide quickly and correctly.	✓	✓
Oral Comprehension — The ability to listen to and understand information and ideas presented through spoken words and sentences.	✓	✓
Oral Expression — The ability to communicate information and ideas in speaking so others will understand.	✓	✓
Originality — The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.	✓	✓
Perceptual Speed — The ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.	✘	✓
Problem Sensitivity — The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.	✓	✓
Selective Attention — The ability to concentrate on a task over a period of time without being distracted.	✓	✓
Speech Clarity — The ability to speak clearly so others can understand you.	✓	✓
Speech Recognition — The ability to identify and understand the speech of another person.	✓	✓
Speed of Closure — The ability to quickly make sense of, combine, and organize information into meaningful patterns.	✓	✓
Visualization — The ability to imagine how something will look after it is moved around or when its parts are moved or rearranged.	✓	✓

Skill Comparison	Engineering Technician	Civil Engineer
Critical Thinking — Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.	✓	✓
Active Listening — Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.	✓	✓
Reading Comprehension — Understanding written sentences and paragraphs in work related documents.	✓	✓
Mathematics — Using mathematics to solve problems.	✓	✓
Speaking — Talking to others to convey information effectively.	✓	✓
Monitoring — Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.	✓	✓
Writing — Communicating effectively in writing as appropriate for the needs of the audience.	✓	✓
Complex Problem Solving — Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.	✓	✓
Judgment and Decision Making — Considering the relative costs and benefits of potential actions to choose the most appropriate one.	✓	✓
Coordination — Adjusting actions in relation to others' actions.	✓	✓
Active Learning — Understanding the implications of new information for both current and future problem-solving and decision-making.	✗	✓
Learning Strategies — Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.	✗	✓
Instructing — Teaching others how to do something.	✗	✓
Negotiation — Bringing others together and trying to reconcile differences.	✗	✓
Persuasion — Persuading others to change their minds or behaviour.	✗	✓
Service Orientation — Actively looking for ways to help people.	✗	✓
Social Perceptiveness — Being aware of others' reactions and understanding why they react as they do.	✗	✓
Management of Material Resources — Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work.	✗	✓
Management of Personnel Resources — Motivating, developing, and directing people as they work, identifying the best people for the job.	✗	✓
Time Management — Managing one's own time and the time of others.	✗	✓
Science — Using scientific rules and methods to solve problems.	✗	✓
Operations Analysis — Analysing needs and product requirements to create a design.	✗	✓
Systems Analysis — Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.	✗	✓
Systems Evaluation — Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.	✗	✓