
# PUBLIC TRANSPORT TECHNICAL TOUR SUMMARY REPORT

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This report outlines the findings from a study tour conducted in June 2019 to experience, view and evaluate the current and emerging global technologies in electric public transit systems (inclusive of trackless trams).

Note: This report was generated as part of a process running in parallel to the SBEnrc 1.62. Some of the resources from this project allowed researchers to be involved in this tour.

Sustainable Built Environment National Research Centre AUSTRALIA

# EXECUTIVE SUMMARY

This report outlines the findings from a study tour conducted 3rd to 15th June 2019. The purpose of the tour was to experience, view and evaluate the current and emerging global technologies in electric public transit systems, inclusive of trackless trams.

The tour was attended by 15 participants from Australia and New Zealand (7 whom only attended the China segment of the tour and 8 the full tour). It brought together industry thought leaders, government and researchers to evaluate:

- Corridor transit vehicles and supporting infrastructure currently in operation, new vehicles and emerging technology
- The potential social, economic, and environmental benefits of transit activated corridors as part of new mobility MaaS ecosystem
- Opportunities for private entities and public authorities to lead the transformation of urban mobility
- The maturity and potential for new and emergent technologies and how these may be utilized within a MaaS operational model to provide an integrated equitable mobility solution and optimal re/development outcomes.

The tour was an information gathering and readiness phase to inform the transition to an integrated mobility ecosystem. It was conducted as part of the development of a transport innovation research centre and to further industry partnerships.

For many the tour was an opportunity to understand -

***"Are trackless trams (CRRC ART and others) a viable alternative to Light Rail?"***

The group concluded that the ART provided an experience comparable to light rail. It was certainly worthy of consideration but that more work was required to assess the feasibility of the ART vehicle due to the limited operating environment and the observed road pavement impacts.

Although the other vehicles were less light rail-like these offered a vastly improved customer experience compared to a traditional bus and are providing a high-quality BRT corridor transit network.

The features of these vehicles included:

- Level boarding
- Contactless, all mode, cross boarder integrated ticketing
- Completely flat floor throughout
- Generous width
- Internal seating suited to trip length
- Floor to ceiling windows
- Wide opening multiple doors
- Study / teen spaces (eg. at back of bus)
- USB chargers/wifi
- Inviting lighting and use of quality interior and exterior finishes eg wood laminates
- Incorporating curated locally-relevant art-work
- Four-wheel steering
- Driver assistance technologies to enable "close to kerb" parking

The lines in operation experienced in Amiens and Malmo did not provide full separation or priority but appeared to support development and induce higher ridership. In a more supportive operating environment these vehicles could offer a high-quality PT with similar benefits of light rail. These vehicles offer an affordable opportunity for expansion of the priority corridor network, particularly in less dense cities.

The 'field of pertinence' a term introduced to the group by Alstom, provides relevant framing for the role and positioning of trackless trams and other conceptual mass transit vehicles within the emerging MaaS ecosystem.

The tour visited several leading examples of transit activated development with outstanding provision of separated cycling and walking infrastructure integrated with PT. Studies in Malmo, one of the cities visited, found that those cycling and walking have higher perceived accessibility and higher social sustainability. The addition of active transport greenways in new developments and the retrofitting into existing urban fabric offers significant social benefits including improved physical and mental health, inclusion, living affordability and amenity. The decoupling of parking and providing end of block garaging seen in Malmo and Freiburg developments has reduced car usage and local area circulation. These garages would also provide an opportunity for community batteries or distributed renewable energy storage, freight delivery lockers and shared mobility stabling and servicing.

The rise of MaaS service providers and the integration of modes are providing commercial opportunities for existing and new investors in transport. An area of interest is the MaaS app that enables trip planning and payment. Sweden was an early integrator of PT service providers and payment and current offerings in Sweden by Ubi-Go and Finland by Whim, provide a unified mobility subscription with multiple operators including micro-mobility and car share in one offering. With significant commercial interest in this aspect of transport provision by MaaS Global, Uber, Google and others, how this is achieved in Australia will be not only pertinent to customer experience and implementation but could impact transit network viability and land development outcomes.

The maturity of the technologies is sufficient that the bus systems viewed are viable for wider adoption and provide benefits of improved service delivery and customer comfort, economic and environmental sustainability. The ART vehicle is also being deployed with a driver, not yet fully autonomous and perhaps always to be that due to it being in mixed traffic. It is however a highly autonomous transit system that uses these technologies to create a highly precise ride quality.

There was a general view by manufacturers that conceptual fully autonomous vehicles will be ready for deployment within 5 years commencing within the public transport sector where dedicated right of way can be provided. This short time frame and the rapid evolution of these technologies in communications and energy storage require urgent consideration in transition planning of infrastructure or system investment.

Overall the study tour reinforced the view that transport is on the cusp of transformational change. In Australia our cities need an integrated approach to get ready for this. We continue to spend money on upgrading and adding to the road network without regard to these imminent changes. This is not resulting in the performance improvements needed by our rapidly urbanising society in safety, reliability, or in a reduction in congestion and carbon emissions. The future transport ecosystem will rely on communications and energy to enable autonomy, sharing, connectivity and e-commerce and there needs to be an integrated vision of how to equip the infrastructure of the future.

***A tour participant provided the following observations on the value of the tour***.

*'The study tour provided an excellent opportunity to observe best practice in transit orientated and transit led development. It also provided exposure to current and emerging technologies for rapid transit, introducing a "dose of reality" to some of the more speculative claims being made by proponents of new technologies. The tour reinforced that while we should strive for transport innovation, change needs to be approached in a controlled and considered way to avoid diminishing transport or place-making outcomes.'*

The tour has highlighted the need to continue with an integrated approach to investigations in this area, particularly as the evolution of these technologies are presently being developed across a number of agencies and different disciplines.

A proposal is being developed under the banner of EMUS – Electric Mobility and Urban Systems - see which has the aim to facilitate collaborative research in the areas of:

**Technology**

- *Vehicles*—second tier transit (trackless trams and others), electric vehicles personal and freight
- *Energy—batteries, charging and storage*
- *Communications—Mobility as a Service,* applications, infrastructure to support V2V, V2G, ITS etc

**People and Place**

- *Route and node*—assess configuration and performance using models
- *Movement and place*—improve integration to identify development opportunities, infrastructure strategy incorporating place (social, economic and environmental)

**Governance and Transition**

- *Transition to new technologies*—community acceptance
- *Alternative funding and delivery methods*— Incentivise investment
- *Risk assessment*

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# Introduction

This report outlines the findings from a study tour conducted 3rd to 15th June 2019 to experience and evaluate the current and emerging global technologies in electric public transit systems (inclusive of trackless trams). The tour was attended by 15 participants, 7 of whom only attended the China segment of the tour.

The study tour brought together industry thought leaders, government and researchers to explore:

- Corridor transit vehicles and supporting infrastructure - currently in operation, new vehicles and emerging technology
- The potential economic, societal and environmental benefits of corridor transit as part of new mobility ecosystems and how this would benefit Australian cities, and
- Opportunities for private and public authorities to lead the transformation of urban mobility.

It was an information gathering phase to provide a sound basis for further investigation and development.

# Background

The tour was part of a broader research project that seeks to further advance the implementation of high-quality second tier corridor transit systems required to support growth and development of Australian cities.

Australia like most countries is investing significantly in transport infrastructure to address increasing urbanisation, rapid population growth and environmental sustainability. The transport sector is rapidly evolving with advances in vehicle, infrastructure, data and communications technology. Australia has the opportunity to lead innovation benefiting governments and citizens through the adoptions of more efficient public transport whilst supporting innovation, our knowledge economy and exports.

There is an imperative to move quickly to progress these new and rapidly emerging technologies to the benefit of Australian cities and position Australia as a leader in this field. As outlined in this and other documents a series of research projects are underway under the aegis of SBEnrc.

The project is proposed to consist of 3 stages.

- Demonstration and Familiarization - to assess the attributes of available vehicles and to produce an evaluation framework that will assist in selecting vehicles suited to community need and the specific urban environment.
- Vehicle and System Testing in Closed Environment - to develop and test a set of system and vehicle standards to ensure resilient, adaptive and compatible interoperable systems - this is most important as the enabling technologies are evolving very quickly and the system will need to be able to adapt to advances in technology As most projects are being implemented to support urban development and regeneration the system will need to be integrated with the existing network and scalable.
- Field Trials - to provide government, industry and community confidence and awareness of the opportunities presented by the technologies through engagement and collaboration.

The tour was an important component of the first stage providing familiarization, technical information and building relationships. The tour supports the development of a proposal currently being prepared with the RAC and Department of Transport to attract investment from governments

and the private sector to establish a research centre that will commission and complete the vehicle and system technology trial and provide guidance on an integrated approach to implementation.

## Project History

The tour follows on the work undertaken by City of Stirling, City of Perth, Town of Victoria Park, City of Canning and Curtin University (Client Consortium) "Trackless Trams from Concept to Reality" that considered the context and feasibility of the technology and that of Sustainable Built Environment National Research Centre (SBEnrc) Project 1.55: "Integrated Cities: Procuring Transit Infrastructure through Integrating Transport, Land Use and Finance". The paper based on this research, "The Trackless Tram: Is it the Transit and City Shaping Catalyst we have been waiting for?" has also been published in an international journal.

**The research determined that TTS technology is worthy of investigation as it potentially offers considerable advantages over available technology.**

These advantages would seem to primarily be the lower cost and disruption to implement compared to light rail whilst still having the appeal of light rail. A TTS could also deliver operational efficiencies, social and environmental benefits transformational to the development of cities and in particular to enable a much greater involvement of private developers in enabling the project to be funded and financed.

The TTS technology is rapidly developing as shown in Figure 1 below. The vehicle offering is diverse and there are currently several manufacturers developing products that will potentially meet the requirements of this emerging global market. The technologies offered by the various suppliers will be required to meet interoperability requirements, so ensuring that implementation would not result in becoming 'captive' to any one supplier. There has been emphasis in the research on the Chinese CRRC ART as this appears to have significant 'crossover innovations' not in other TTS. Hence the tour included a visit to Zhuzhou to enable participants to view this vehicle before continuing on to Europe to see other tram styled vehicles and then attend the UITP Expo and Conference.


*Figure 1: Trackless Tram Type Vehicles*

## Itinerary and Participants

The tour included two segments, a China only segment primarily arranged for participants to experience and evaluate the ART vehicle and autonomous vehicle technology, and a European segment. The European/Scandinavian segment was set up to provide a comparative assessment of technologies and how this may integrate with the broader electric mobility ecosystem. The segment focussed on emergent transport technologies and other electric trackless tram like vehicles in operation in Europe as part of the MaaS integrated public transport network. It also explored leading

transit-oriented city examples and how the lessons from these might inform the adoption of emergent transport technologies in the Australian and New Zealand context.

Of the 15 participants 7 attended the China only segment.

**Itinerary**

- 3 -4 June - travel to Hong Kong group assembles in Hong Kong
- 4 June -Hong Kong to Shenzhen by train
- 4-6June - Zhuzhou CRRC Zhuzhou Times Electric Co visit to evaluate the ART
- 7 June - Amiens to experience the Nemo BRT and Paris meeting with Alstom
- 7-8 June - Stay Freiburg, visiting Vauban and Reisenfeld
- 8-12 June - Stockholm UITP conference, green TOD visits Hammarby Sjöstad and Barkaby
- 12-13 June - Gothenburg
- 13-14 June - Malmo
- 15June travel home via Copenhagen

**Participants - Full Tour (Day 1 to 10 inclusive)**

| | | |
|---|---|---|
| Marie Verschuer | Consultant/Researcher | Bodhi Alliance |
| Dr Neville Binning | Consultant/Researcher | EDAB Consulting |
| Nigel Hindmarsh | Director of Development | Dept of Communities WA Govt |
| Fraser Henderson | Manager City Planning | City of Stirling |
| Edward Steane | Project Director 15th Avenue Transit Corridor | Liverpool City Council NSW |
| Andrew Stevenson | Manager Communications | Liverpool City Council NSW |
| Alan Kerr | Consultant | Stantec |
| David Stuart-Smith | Consultant | Arup |
| **Participants -China Tour (Day 1 to 3 inclusive)** | | |
| Dr Brad Petitt | Mayor | City of Fremantle WA |
| Philip St John | CEO | City of Fremantle WA |
| David Brodhag | Technical Leader Autonomous Vehicle Trials | RAC WA |
| Dr Mike Mouritz | Research Fellow | Curtin University |
| Dr Yuan Gao | Research Associate | Curtin University |
| Dan West | Research Associate | Curtin University |
| Vinnet Ndlovu | PhD Candidate | Curtin University |

## China Tour Segment

**3 -4 June Monday - travel to Hong Kong group assembles in Hong Kong**

**4 June Tuesday -Hong Kong to Shenzhen by train**

- Shenzhen Haylion Technologies Co. Ltd demonstration of bus autonomy in open operation in a business precinct. Haylion focuses on intelligent driving technology for public transport, integrating electrification, intelligence and shared-mobility services technologies, to improve the overall service quality and level of safety urban public transportation. Scania has engaged Haylion to assist with their development of autonomous vehicle technologies

**4-6June Tuesday Thursday Zhuzhou**

- CRRC Zhuzhou Times Electric Co visit to evaluate the ART vehicle (Chinese Trackless Tram). Visit included riding the ART on the Zhuzhou line. This was the first public transport service line utilising the ART vehicle, the line opened in May 2018 and runs on a 3.5km route at

15minute intervals. Visit also included factory visits and workshop on the ART vehicle to better understand the requirements for trialling the vehicle in Australia.

## Haylion Shenzhen

The Haylion visit in Shenzhen provided an example of the maturity of world leading autonomous vehicle technology. The vehicle, a 12-metre bus was being operated in an open environment within a business park. This environment was well suited to the technology with buildings being predominantly 2 storeys on the street and those 5 storeys or more set back from the road. This built form configuration would be less likely to impede the GPS and V2X communications. The vehicle was equipped with cameras, LIDAR, radar and GPS systems. It attained speeds of 50kph. It was programmed to be less reactive to normal activities such as pedestrians approaching cross walks etc than similar vehicles. However, the ride was still jerky and at one stage the pilot took control to avoid an incident with another vehicle encountered on a blind corner.

The group was of the opinion that the technology as displayed was not yet sufficiently mature for widespread public operation as it did not provide a comfortable passenger experience.

## Zhuzhou CRRC Times Electric Co ART Trackless Tram

The tour visited the CRRC factory, rode the CRRC Autonomous Rapid Transit (ART) vehicle operating on the 3-kilometre demonstration line in Zhuzhou, and attended a technical workshop hosted by CRRC engineering staff.

*Figure 1: ART Station with overhead charging*

The participants were agreed that the ART provides a comparable light rail experience. Due to the limited operating environment of the demonstration line (being straight, level, newly surfaced, separated centre running within a wide reserve and 6 lane corridor, 40kph speed) questions still remained as to the limitations of the technology including:

- The rutting of the pavement in parts resulting from 1 year of operation suggests the ART in its current form is likely to require a higher quality pavement, at least in certain areas of road. This would increase the capital cost and impact of construction;
- The ART demonstration line was flat and straight and the vehicle did not exceed a speed of 40-50kph. As such it was difficult to assess the performance of the technology, with no revenue service routes currently in operation (with hills and/or curves).
- CRRC does not appear to be actively marketing the product (no presence at the UITP Expo and Conference by the Times Electric Co. The subsidiary companies of CRRC were displaying high speed rail, light rail vehicles and electric bus) though they are generating a presence at Qatar for the Soccer World Cup.

- The ART uses all systems to operate autonomously (LIDAR, radar, GPS and visual line guidance) and cannot achieve full autonomy without all systems available. This limits fully autonomous operations and requires the presence of a driver. The full autonomous capability of the vehicle was demonstrated and it is possible that this function could be utilised within specific circumstances such as within the depot or station docking (similar to the Alstom LRT trials) where the necessary enabling infrastructure exists. This staged adoption would assist technology refinement and acceptance. It is noted that signalling and communications infrastructure is required and the introduction of 5G will further support autonomous vehicle deployment.
- Due to pavement damage at stations the vehicle did not autonomously dock at those impacted stations within a distance compliant with disability codes, this was achieved with driver intervention. In the previous visit when there was no rutting the vehicle was able to achieve very close docking without driver intervention.

A trial commenced in Qatar in 2020 and another 9km public service opened in Yibin China in July 2019. The operations of these lines will provide further insight into the feasibility of the vehicle.

It was agreed that a trial as being proposed by Curtin University RAC and WA Government (with possible involvement of New Zealand) is necessary to consider the above matters. This trial is imperative before any progress can be made in considering the vehicle for an Australian use case. Future visits should take the opportunity to view the ART's capacity to deviate from the chosen route under manual control from the driver and to ride it on the test track where higher speeds can be attained. Not only would this test whether this function is realistic, but also would give a good indication of the ART's comfort in real-life conditions when going around corners and over cambered roadways.

The CRRC supported the idea of the trial. The CRRC agreed in principle that they could provide a trial vehicle if the expenses of the trial were covered. The CRRC would seek to achieve vehicle familiarisation, a pathway for compliance and approval to operate and evaluation of how the vehicle might be improved.

Post tour consideration relating to pavement by Stantec and Arup is provided below:

- Although the ART has a 4 ½ T wheel load, we assume that it will tread heavily due to a relatively high un-sprung mass – each wheel has a hub motor and steering equipment.
- The ART wheels are an odd size and the single tyre is having a significant influence on the point loading, which is evidenced by the observed rutting on 'normal' pavements.
- Pavement construction may involve up to 1.0m deep granular pavement, and around 0.5m with Foam Bitumen Stabilisation (FBS), all with structural AC layers. The pavement itself will be somewhere between $1.2M-$1.9M per lane.km. This doesn't include establishment, QA, traffic management, and line marking.
- There are other possible options, e.g. cement stabilisation, but that will require quite high percentages of cement, and there are other issues associated with this, however the cost will be similar.

*Figure 2 - Zhuzhou pavement deformation at ART station*

## Europe and Scandinavia Segment

- 7 June Thursday Amiens to experience the Nemo BRT and Paris meeting with Alstom
- 7- 8 June Stay Freiburg, visiting Vauban and Reisenfeld transport oriented urban developments
- 8-12 June Stockholm UITP conference and green TOD visits to Hammarby Sjöstad and Barkaby
- 12-13 June Gothenburg
- 13-14 June Malmo
- 15June travel

### Amiens

- 7 million km covered per year
- 16 million annual journeys predicted by the end of 2024
- 4 BRT Nemo routes, including three fully electric ones, representing 70% of total passenger numbers
- 110 accessible and comfortable BRT system stations, with USB sockets on the seats
- service from 4am to midnight
- 14 Tempo lines (previously school bus routes)
- 12 "convenience network" bus routes providing neighbourhoods with comprehensive coverage, connected to the Nemo routes via transfer hubs
- 1 free city centre shuttle
- 4 on-demand transport services
- 2,000 short-hire and long-hire rental bikes, including 970 e-bikes
- 4 open park-and-ride facilities on the outskirts of the network where people can easily park and then use public transport to get into the town centre in 15 to 20 minutes
- 1 car-sharing service (to be launched soon)
- 470 employees

In Amiens the group were met by the operator Keolis to view the Irizar ie tram that services the Nemo network (Keolis also operate Mettis network utilising the 24m Van Hool Exqui.City in Metz), the Irizar

sales manager and the commissioning representative. The Nemo BRT consists of 4 routes, 3 of which are fully electric. The vehicles use 5-minute opportunity charging at route termini and overnight slow charge. The operation centre and depot are collocated and the facility included a servicing workshop and overhead pantograph charging stations for each vehicle.

*Figure 3: Depot pantograph*

The Nemo had been opened less than 3 weeks when viewed and the MaaS integrated system as planned was not yet fully operational. It was intended that the 4 route BRT would run in dedicated lanes, have signal priority, be supported by a control room and be complemented by 2,000 share bicycles, on demand feeder local area transit and autonomous city shuttles. When visiting none of this was yet operational. An advantage of a BRT system is the ease and speed of implementation, evidence suggests there is also the risk of lower investment and focus on placemaking, supporting infrastructure, network rationalisation/integration and development when compared to light rail.

The group considered the Irizar ie-tram to be an attractive, commercially-available example of the technology that could be operated along a rapid bus route in Australia and New Zealand immediately, pending approvals and meeting compliance requirements. As with all European vehicles the ie tram is non-ADR complaint due to width being 2.55m not the Australian 2.5m standard.

*Figure 4 - Amiens concrete pavement at station*

Other aspects of the Amiens Nemo system included the use of concrete pavement section to address potential wear or rutting from repeated docking at the same position at stations. The depot and control centre design provided a good example with architectural merit. The use of art is similarly innovative, reinforcing the modern identity of the bus service and encouraging community recognition and enthusiasm.

The absence of transit orientated development around stations and the positioning of the terminal stations in uninhabited areas serviced by park and ride suggest that development was not a key objective of the service but rather it was designed for mode integration, service and cost efficiency.

## Alstom

Visit to the Alstom Innovation Centre in Paris. The visit included a presentation by Alstom on their public transport offering, innovation and development of vehicle autonomy and alternative electric charging systems. As the company responsible for the maintenance of the Translohr vehicles operating on lines 5 and 7 of the light rail network in Paris the discussion also covered the operational challenges experienced for the first trackless trams that have been in operation since 2007.

The Alstom model of the ***field of pertinence***, presented below is quite helpful for understanding the different roles that bus, trackless tram, and light rails can have.

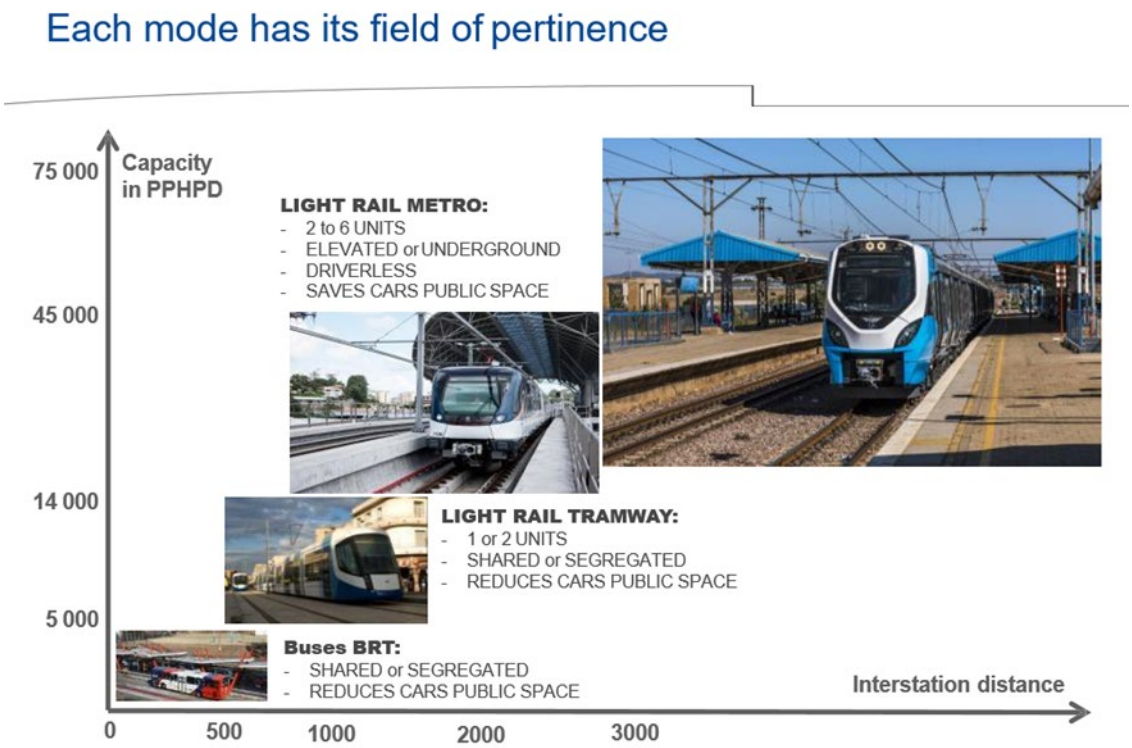


*Figure 5 'Field of Pertinence' Alstom 2019*

The tour group agreed that the trackless tram potentially offers a cheaper way of delivering almost the same capacity as light rail and with a much better user experience than bus but where does it fit within the field of pertinence? It costs more than a bus, but less than light rail and can carry almost as many as light rail.

## Reisenfeld

The tour travelled by train to Strasbourg and then by bus to Freiberg with the objective of visiting the transit-oriented developments of Reisenfeld and Vauban.

Reisenfeld is a medium density residential development was constructed on a former wastewater treatment site in the early 2000's. The development orientated around a light rail line that runs through the town is a 15-minute trip to Freiberg. Reisenfeld has a reasonably high level of car ownership and on-street and garages attached to homes would make this form of development very

familiar to Australians. The inclusion of greenways and lanes dedicated to pedestrians and cyclists provides a high level of amenity and accessibility. Development has aged well in the community with a strong sense of passive surveillance and community safety, it was noted that there was no lighting on paths and laneways with lighting provided through light spill from adjacent homes. The neighbourhood ends with a public park which separates the medium-density residential from surrounding farmland.

*Figure 6 - Reisenfeld green track for the light rail*

## Vauban

Vauban is another suburb of Freiburg where a greenfield development sought to showcase sustainability and transit-led development. In Vauban parking is decoupled from housing and there is very low levels of car ownership. The community is very sustainability focussed with a number of alternative and organic retailers, one point that was noticed was the lack of coffee shops and restaurants in the suburbs with these being located in the town centre encouraging community gathering, vibrancy and a sense of ownership of the old town. There are bicycle lockers adjacent to bicycle paths for convenient safe storage of bicycles. Car use is discouraged within the residential area with speed limited to 5kph with the neighbourhood. The suburb has less diversity having attracted well-educated and advantaged like-minded residents. Vauban has car sharing and a solar garage, with a supermarket underneath similar to those in Malmo.

*Figure 7 - Bicycle lockers in Vauban*


*Figure 8 - Solar garage Vauban*

## UITP

The conference held in Stockholm from the 9-12 June covered all facets of urban mobility from high speed trains to electric scooters and bicycles. The conference had 2,718 attendees from 81 countries and over 15,000 Expo visitors.

Themed "The Art of Public Transport" the focus was on the innovation occurring in public transport. The programme also included a mini documentary "Redefining Public Transport, produced by BBC StoryWorks https://vimeo.com/341123176

The UITP Conference and Expo showcased current and conceptual products from 474 exhibitors. There were 53 Congress sessions featuring 300 speakers covering the topics customer service, safety, governance, integrating new mobility into public transport systems, operating electric vehicle fleets, artificial intelligence, ticketing, trip planning and MaaS, deploying autonomous vehicles, using big data for efficiencies in PT, project delivery.

In Stockholm, in addition to attending the UITP Conference (see conference notes below), the group visited the Hammarby Sjöstad precinct. This area is renowned as an international best-practice example of medium-density development with a particular focus on sustainability and resource circularity.

At Hammarby Sjöstad we observed the relationship of development with the new light rail line, with development densities/heights cascading away further from the light rail line. The cross-sections were interesting with the light rail line using a sleeper-based system at stations with “green tracks” using a ladder system between stations. This reduced the permeability of stations, but would have enabled the light rail system to be delivered at a lower cost.

*Figure 9 - Hammarby Sjöstad*

Another notable feature of Stockholm was the use of art throughout the city’s metro stations. Each station has a distinctive artistic identity curated with professional artists. While this program has maintenance challenges (including keeping art curation appear vital and interesting) and while art works – if not carefully selected – can present maintenance and operational challenges, nonetheless the art program is considered by the City of Stockholm to play a significant role in the success of the metro system.

Stockholm Transport is now rolling out the art in stations program to key bus stations and light rail stations to, with the Slüssen bus station next scheduled for art installation and treatment. As noted above, commissioned art has also been included in the design of the new Ameins bus system,). Discussion at the UITP conference indicated, from Gothenburg, London, Strasbourg and Stockholm experience that there are three key benefits from art in public transport:

1. Enhanced perception by users of public transport. The Strasbourg public art scheme was deliberately introduced in 1994 with the new tram system to respond to potential negative perceptions by local residents of a return of tram technologies;
2. Improved community ownership of public transport system with enhanced sense of safety and a desire to maintain and support assets; and

3. Improved wayfinding by providing non-verbal cues on station, and the location of services and facilities within stations. This is particularly useful for non-native speakers.

Hammarby Sjöstad provided a further example of the innovation available in medium-density urban development. There is a potential opportunity for art to be used as a low-cost "point of difference" on the rapid bus corridor from the city centre to the new airport. Art might be used to lift the perception of key stop locations, encourage the community to see them as a "different type of transport" and reinforce the place quality of these locations. One option may be to involve Casula Powerhouse Arts Centre and draw on their reputation for high quality, innovative art curation. The Centre could, through funding from the FAST Project construction and operational budget, curate signature art installations at each of the five to six key station locations along the route.

This will have ongoing maintenance and curation costs but, adopting a wider economic benefits approach, has the potential to significantly influence patronage and property development in the surrounding area. Note that in Stockholm, approximately 1% of station development costs are set aside for art installation, whereas in Los Angeles this figure is closer to 0.5%. In London, art is required to be self-funded (e.g. through corporate ownership). Note also the comments below from the UITP conference of the importance of government retaining control of art curation (rather than the project architect or constructor).

**Barkaby**

Barkaby was touted to be the world's most modern transport city with sustainable and modern solutions including autonomous door-to-door shuttles, electrified BRT, pilot with autonomous 12m city buses combined with commercial new mobility in a MaaS-solution. The group caught a train to Barkaby and then a connecting bus into the town centre. The town was dominated by a large shopping outlet mall and surrounded by farm land. The train station had very poor connectivity to the buses that were required to take people from the station to the town as this was not within easy walking distance. The buses were infrequent requiring a wait at the station that had no other services and not all bus stops were undercover. The Easymile shuttle was slow and jerky reflecting the mapping and maturity of the system. Much of the town and the system was still under construction and did not provide a simple or intuitive MaaS experience. The lesson learned was if the train station is not conveniently located to the town centre then frequent shuttles that have a good connection to the platform is required.

In Barkaby for the traveller the MaaS provision was not immediately evident and accessibility seemed very poor. It is likely that residents have a MaaS subscription and are well served by on demand transit, share cars and micro-mobility.

Sweden was an early integrator of PT service providers and payment and current offerings in Sweden by Ubi-Go and Finland by Whim, provide a unified mobility subscription with multiple operators including micro-mobility and car share in one offering. With significant commercial interest in this aspect of transport provision by MaaS Global, Uber, Google and others how this is achieved in Australia will be not only be pertinent to customer experience and implementation but could impact transit network viability, visitor accessibility and land development outcomes.

**eRoadArlanda**

A visit was made to the test site to view the eRoadArlanda project. https://eroadarlanda.com

Two kilometres of rail is embedded in the road located between the Arlanda Cargo Terminal and the Rosersberg logistics area. A truck fitted with a spigot makes contact with the rail and is charged whilst moving. The operation was easily achieved and resulted in some noise as metal made contact with metal, raising questions on the long-term durability of the solution. The project is a part of the Swedish Transport Administration's pre-commercial procurement of innovation, through which the technology is tested and further developed. The investment in the eRoadArlanda project is in line with the Swedish government's target of creating a fossil-free transportation infrastructure by 2030-2050 and will help to boost Sweden's competitiveness. It was thought that this technology had more relevance to freight than to metro transit where other more suitable recharging could be utilized. However, the partnering research model was interesting and will be explored further.

*Figure 10 Road Embedded Rail Charger eRoad Arlanda*

## Gothenburg

In Gothenburg we visited a major new property development being undertaken by Serneke, a development company. Gothenburg is the second largest city in Sweden and historically was an automotive manufacturing hub. It still has some automotive presence (through Volvo, and Volvo's parent company). Gothenburg has leveraged this to position themselves as an automotive technology hub and they are now referred to as the "Scandinavian Silicon Valley". Unlike Silicon Valley the cost of living is considerably lower than Stockholm, although the area is rapidly growing.

The development at Lindholmen is located in an area historically used for port operations. The area was socially depressed through the 1990's and early 2000's but has now been rejuvenated through medium-density development, the development of a new university, and the establishment of a "Science Park".

The local government is engaging with the community to involve and educate them on the vision and sustainability objectives. This includes a temporary biodome and a large immersive model for the community to see new development. These facilities, and particularly the immersive model, were popular with the local community and all age groups. The developer noted that they were careful to site supermarkets in locations that would otherwise be "dead spaces" to help activate those areas and encourage movement. The development also has an indoor green bus stop, with freight lockers, lounge area and library, café and share bike and autonomous shuttle connection.


*Figure 11 – Lindholmen cross-section*

The development area already has a significant amount of medium density development, orientated around a rapid bus way with a pleasant tree lined cross-section. The rapid bus way will be upgraded to light rail as part of the development of the area (including, particularly, the construction – now underway – of a 75-storey building by Lindholmen as a centrepiece of the development.

The light rail is being wholly funded by the local government (with no direct contribution from the developer), although 80% of revenue from congestion charging in Gothenburg, which includes the area, is hypothecated to public transport capital investment. All businesses are also required to pay a hypothecated tax for public transport for their employees. Interestingly, the developer noted that it made little difference to them whether there was rapid bus or light rail connection to their development (in terms of the density they would deliver). An additional feature of the development is the city's plans to connect the area to the central station (across the river) and to neighbourhoods further afield using a cable car. Of interest was the shared corridor running of the buses and light rail.

**Landvetter Sodra**

A separate meeting was arranged for the Liverpool City Council representatives with Maria Ådahl and Amanda von Matern from Landvetter Södra Utveckling AB, a fully owned company of Härryda kommun (the local municipality). Härryda kommun is a municipality of approximately 290km$^2$ and has a population of almost 40,000 people. Härryda kommun is home to Göteborg Landvetter Airport, Sweden's second-largest airport (c. 7MPA) and Landvetter Södra Utveckling AB has been established to develop a new urban centre approximately 3km from the airport site, and 30km from Gothenburg. This project has strong similarity to the Western Sydney Airport project.

It is intended that Landvetter Södra Utveckling will be a city of approximately 25,000 inhabitants across an 800ha site owned by the municipality. Six developers have been selected to develop the site with development expected to commence in the mid 2020's. The municipality is currently lobbying the Government for the new airport rail line to the airport to include a stop at Landvetter Södra Utveckling. Maria and Amanda advised, however, that they also envisage bus rapid transit in the short term. The meeting enabled a collaborative relationship for knowledge sharing between the two Liverpool CC and Landvetter Södra Utveckling AB.

The key take-out from urban development in Gothenburg was the cross-section used for the rapid busway through the medium density development. The cross-section was attractive and effective and had the same functionality (i.e. tree-lined, rapid bus transit, one general traffic lane in each direction, pleasant and affordable place-making that is effective in providing transit and permeability to the surrounding community).

## Malmö

The tour visited Malmo the first Swedish city to operate a BRT system introduced in 2015, winner of the European sustainable urban mobility award in 2016 and one the first cities to adopt a sustainable urban mobility plan (SUMP). Malmo has used integrated transport and urban development to transform a failing industrial town into a world leading example of sustainable development.

Today 30% of commuter trips in Malmo are made by bicycle. This park and ride culture is supported by 500km of cycle paths and a 1,500 place uncover bicycle parking at the Central station. The BRT system consists of the Van Hool Exqui.City 24metre bi-articulated, biogas/electric tram like vehicles running on partly separated lanes with signal priority. Since the introduction of the system passenger ridership and capacity has increased and travel times and emission have decreased and there has been improved passenger experience. The bio-gas plant is located in the town centre near to the Central station and convert waste to energy.

The visit to Malmö enabled us to observe the Van Hool Exqui.City in revenue service. Malmö does not have a light rail operation, but instead uses a mixture of bus types including the bi-articulated Van Hool vehicle. All the Van Hool's we experienced were biogas hybrid. The Van Hool's had a tram-like exterior, but interior design and comfort levels were akin to a conventional bus. There was some discussion about how well the Van Hool's design will age.

*Figure 12- Van Hool Exqui.City Malmo*

**Västra hamnen**

An attractive new development area of Malmö the Västra hamnen neighbourhood was formerly an industrial area. In the early 2000's there was a design expo, followed by the establishment of a

governance model where developers could purchase development rights in return for participating in a developer-led governance body which set design rules and infrastructure controls etc. Over time the city council has released land to this body, and a highly sustainable mixed-use and medium-density development has occurred. This development was designed by the city to lead Malmö's renaissance as a "sustainability city". Malmö had previously been a major industrial and auto-manufacturing hub but was poor and had a negative reputation by the early 2000's.

The neighbourhood itself was very attractive with key features including:

- Recreational spaces between the development and the sea, ensuring genuine public access to the most attractive areas
- Children's play areas between developments in order to enable passive recreation
- A variety of architectural styles (albeit within the same design envelope)
- Careful curation of commercial uses, for example placing supermarkets (as high traffic generators) at edge of development area under carparking buildings to activate these places
- Development orientated around an iconic building (the "twisting torso", the tallest building in Scandinavia)
- A very pleasant area of Sydney-style terrace houses orientated in a wedge, adjoining mews style housing and a waterway parkland.

The city of Malmö allocated plots to the developers who had purchased rights based on its judgment of the developers' participation in the Owners' Group and their selection of architect. The city's criteria for approving architects was based on their level of experience in sustainable design and an assessment of the quality of the work their firm had built to date. The city felt that this would ensure both a consistently high quality of design and a strong commitment to sustainability. There were a few cases in which the city rejected a developer's choice of architect on one or both of these grounds. See: https://www.balticurbanlab.eu/goodpractices/v%C3%A4stra-hamnen-area-bo01-waterfront-regeneration-malm%C3%B6

The area is still under development, with commercial buildings now also being repurposed for a new convention centre. Vegetation is still relatively small, indicating the benefits of planting area earlier in the development process to enable maturation of vegetation. The development is orientated towards sustainability, rather than transportation. There is still relatively high volumes of car movement (albeit at relatively slow speeds) and the only public transport service is by way of bus (both Van Hool Hybrids and other models). The street cross-sections used a side-running painted bus lane which, it was agreed by the travelling party, was less attractive than the busway cross-section observed in Gothenburg.

*Figure 13 - Västra Hamnen road cross-section*

Malmö shows the opportunity for redevelopment to lead, rather than follow, an urban repositioning and city branding exercise. Malmö leveraged its close location to Copenhagen and has cross boarder transport ticketing enabling easy commuting.

## Summary - Europe and UITP TODs and MaaS

The European/Scandinavian segment provided an opportunity to compare technologies and assess how these may integrate with the broader electric mobility ecosystem. The segment focussed on emergent transport technologies and other electric trackless tram like vehicles in operation in Europe as part of the MaaS integrated public transport network. To view alternative tram like vehicles in operation the tour visited Amiens in France and Malmo in Sweden. Other alternatives were viewed on display at the UITP Expo in Stockholm. The tour explored leading transit-oriented city examples and how the lessons from these might inform the adoption of emergent transport technologies in the Australian and New Zealand context.

The tour found there to be a wide variance in the quality of electric buses with most having look and feel of a conventional bus. It was considered that although the electric operation provides a smoother and quieter ride the electric vehicles alone may not be perceived by patrons as different enough to induce increased ridership or support redevelopment. The example viewed suggest that stylised electric buses that provides a more tram like service have a higher quality image and that this together with improved access have resulted in increased ridership and support city development.

Other vehicle specific features that can help achieve this are:

- Level boarding
- Contactless ticketing
- Completely flat floor throughout

- Generous width
- Floor to ceiling windows
- Opening doors on both sides
- Opening door at very rear of vehicle
- Study / teen spaces (e.g. at back of bus)
- USB chargers/Wi-Fi
- Inviting lighting and use of quality interior and exterior finishes e.g. wood laminates
- Incorporating curated locally-relevant art-work
- Four-wheel steering
- Driver assistance tools to enable "close to kerb" parking

The Irizar i.e.-tram and the Van Hool Exqui.City are two leading examples of vehicles that were experienced in operation and these meet most of the above attributes. Studies undertaken by transport agencies of services in Metz, Malmo and Belfast have found that the vehicles are well regarded by patrons and have resulted in increased patronage by approximately 30%.

Other vehicles such as the Alstom Aptis[1] a 12metre smaller vehicle are also proving to provide an enhanced passenger experience and have attracted industry support with orders for the vehicle exceed the capacity to supply. The Scania NXT, the and the Mercedes e-Citatro concept are examples of concept buses that are not yet commercially available, but take the passenger experience further.

There is a clear and rapid shift in the bus industry towards electric vehicles. Almost 95% of the vehicles displayed at the UITP conference were electric (battery/fuel cell).

Implementing electric bus technology carries potential operational risk, and a critical role of Government will be to work with operators to manage this risk and ensure high quality service delivery for customers. Electric buses are currently more costly to purchase than internal combustion engine (ICE) equivalents. This cost differential is reducing rapidly as battery technologies evolve and production capacity increases.

The operational cost of first-generation vehicles is higher due to battery capacity and range with fleet management requiring more buses to achieve the same service-level. This is no longer the case with improvements in battery density and range.

The maintenance costs of electric vehicles is 25% less than ICE equivalents and this will reduce further as the industry adapts with greater availability of skills and services.

The charging of electric buses can occur through either: (1) Opportunity charging – where the bus is "refilled" with electricity while on service (normally at each end of the route for approximately 20 minutes); (2) Flash charging where super-capacitors enable a 40 second top up; and (3) Slow charging – where the bus is "refilled" over the course of a number of hours at the depot (eg. overnight). Battery configurations and density are evolving and it is important to factor in changes when considering the need and place for on route charging.

The modernisation and electrification of buses and the improved service efficiency achieved through corridor transit systems, along with high quality urban design and station infrastructure, are expected to overcome the community bias against buses. There are relevant examples in using art strategically to also improve the perception of public transport. In Strasbourg art was used widely to overcome community reluctance to the re-introduction of tram technology. Similarly, in Amiens the new BRT



[1] Note that Alstom has advised that with significant orders resulting in a 5year order delay they have no current plans to retail this vehicle outside of France.

uses cartoon images of Jules Verne curated from local artists to identify their buses. Note that advice from Transport for London is that a quality art strategy requires direct Government oversight (it can't be left to the consultant or builder to deliver).

**Network Design and Operations**

Of interest were the examples where trackless tram or BRT vehicles had been used to redesign the bus network making it legible, faster and more efficient and appealing to riders. Malmo was one of the first cities to complete a detailed sustainable urban mobility plan (SUMP) now considered best practice. A SUMP provides quantitative and qualitative evidence on demand, and how it might be met. A SUMP not only informs infrastructure investment, but also how infrastructure decisions once made can be woven into the local fabric to maximise the benefit of the infrastructure investment for both current and future communities.

A SUMP needs to consider:

- Anticipated land-use changes and preferred development patterns
- Demographics and how they relate to job locations (e.g. blue collar jobs vs. tertiary-educated jobs)
- The relationship between different modes (e.g. bus/rail/cycling/scooter/walking/last-mile services/car-sharing/taxis) taking a "mobility as a service" approach
- The relationship of movement to congestion and parking. Where are the opportunities and where are the threats?
- The actual use cases in the community. How do people currently get around, and why do they do that? What do we know of how future communities will behave?

**Sustainable Reuse**

Hammarby Sjöstad, Malmo and Copenhagen all showcased the potential for urban developments to be part of a circular economy, with careful management of resource needs and the incorporation of wastewater treatment plant and rubbish recovery centre is immediately adjacent to the community developments providing resources to provide energy and water.

**Technology Maturity**

The maturity of the technologies are sufficient that the bus systems viewed are viable for wider adoption and provide benefits of improved service delivery and customer comfort, economic and environmental sustainability. The ART vehicle is also being deployed with a driver, not yet fully autonomous.

There was a general view by manufacturers that conceptual fully autonomous vehicles will be ready for deployment within 5years commencing within the public transport sector where dedicated right of way can be provided. This short time frame and the rapid evolution of these technologies in communications and energy storage require urgent consideration in transition planning of infrastructure or system investment.

Overall the study tour reinforced the view that transport is on the cusp of transformational change. In Australia our cities and we need to an integrated approach to get ready for it. We continue to spend money on upgrading and adding to the road network. This is not resulting in the performance improvements needed by our rapidly urbanising society in safety, reliability, or in a reduction in congestion and carbon emissions. The future transport ecosystem will rely on communications and

energy to enable autonomy, sharing, connectivity and e-commerce and there needs to be integrated vision of how to equip the infrastructure of the future.

**Discussions and Considerations**

- Understanding the relative role of bus, trackless tram and light rail and how it fits within the new MaaS paradigm;
- The importance of a consistent position supporting all forms of high-quality public transport;
- Avoiding the trackless tram being seen as a stand-alone solution rather than part of a holistic integrated public transport investment;
- Opportunities to strengthen the support for the trackless tram through the research hub and the City Deal or partnered programs;
- Understanding and resolving the barriers to implementation.