Trackless Trams and Australian Urban Fabric

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Abstract: There is growing interest in the concept of Trackless Trams as part of the suite of transport technologies available to help shape more urban outcomes. However, there is much more for decision-makers to consider than the vehicle itself. This paper discusses both the city shaping possibilities of these systems and the challenges and opportunities inherent in integrating new technologies into existing city systems. Informed by studies, field trips and current trialling of the technology this paper documents the history of the trackless tram from rail to optically guided bus with level 4 autonomy. It describes the potential role of integrated transit systems anchored by Trackless Trams in transforming our cities from car-dominated roadways to green interconnected living streets or activated transit corridors with new urban centres. The paper then applies the technology to Australian cities using the theory of urban fabrics and how it can assist urban regeneration in all three fabrics: walking, transit and automobile urban fabric. A framework of seven design approaches is used to see how the Trackless Tram could be integrated into the urban regeneration process. It uses work done in Townsville, Sydney, Melbourne and Perth as case studies to illustrate how Trackless Trams could help transform Australian cities in various urban fabrics across their cities. New governance systems and changes to planning rules will be needed to deliver this.

Key words: Trackless Tram technology, urban regeneration, theory of urban fabrics, transit activated corridors

Introduction

Trackless Trams are providing a new approach to urban transit through delivering a potentially much more ‘light rail-like’ transit system at around the price of buses. This is done through an optical guidance system developed for high speed rail that means it does not need steel wheels on steel tracks, as well as using new technology batteries that mean it is electric without needing an overhead catenary. The system can carry the patronage of a light rail with similar ride quality and therefore has potential to compete with cars. Being electric its impact locally on noise and air quality is significantly better. It therefore appeals to developers and local/state planners looking to increase urban regeneration around transit routes and especially stations where buses have so far failed. This paper therefore examines the technology in terms of its potential to achieve common good planning outcomes so that a city can simultaneously improve transit and housing/jobs outcomes in different parts of the city. It uses Australian cities as case studies based on a research project involving four Australian cities for the Sustainable Built Environment National Research Centre (Newman, Mouritz, et al., 2018; Newman et al., 2018).

The paper uses the Theory of Urban Fabrics (Newman, Kosonen, & Kenworthy, 2016) to enable a better understanding of how land development mechanisms are inherently linked to transport technologies and what this means for creating urban revitalisation and regeneration. The paper uses a Framework developed in 2019 for the SBEnrc comprising seven design principles and associated practices to inform the qualities needed in creating urban regeneration projects based on transit systems like Trackless Trams. The Framework is then conceptually applied to four case study urban fabrics from the four Australian cities, showing how solutions should differ in emphasis but still have important shared approaches.

Trackless Trams

In a previous research project that has been developed with a series of partners seeking to deliver a light rail-based urban regeneration approach we have created a model for how transit and land development can be integrated with private finance to enable urban regeneration (Newman, Davies-Slate, & Jones, 2018). The project was given a significant boost when the new transit technology of Trackless Trams was discovered. The Trackless Tram Systems (TTS) have taken six innovations from High Speed Rail, put them in a carriage bus – or tram like vehicle, with stabilization through bogeys and optical guidance systems, that not only mean it is largely autonomous (though not driverless) but it is also enabled to move at speed down a road with the ride quality of a light rail. Being electric through batteries and with no need for steel tracks, it is significantly cheaper and easier to implement than a light rail. Research was conducted on assessing this technology (Newman, Hargroves, et al., 2018) and the conclusions are presented in Table 1. The crosses indicate major problems, the ticks give the level to which these are solved.

This Trackless Tram Systems assessed here lean towards the one created by CRRC in China as it has the most developed optical guidance system that controls ride quality. However, there are other Trackless Tram Systems that are developing in Europe that could also be used to create better people-friendly and place-based urban spaces that are not affected by excessive traffic. Table 2 summarises the evolution of these systems and summarises the qualities that seem to characterise their progress (Newman, Mouritz, et al., 2018).

Table 1. Indicative comparison of characteristics of corridor based urban rapid transit systems

Characteristic	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Trackless Tram System (TTS)
Speed and Capacity	✓	✓✓	✓✓
Ride Quality	✗	✓✓	✓✓
Land Development Potential	✗	✓✓	✓✓
Cost	✓	✗	✓
Disruption during construction period	✓	✗	✓✓
Implementation Time	✓	✗	✓
Overall	✓	✓✓	✓✓✓

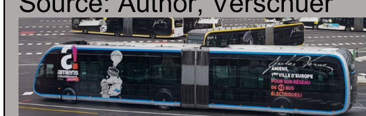
Source: Newman, Hargroves, et al., (2018) pp31-55.

In 2001, the Guided Light Tram (GLT) rubber tyred vehicle was manufactured by Bombardier guided by a single central rail. But due to the system costs, limited reliability and maintenance issues this GLT became unsuccessful. In 2007, Translohr was built within a modular design which addressed the conditions of coming off the guide rail and pavement rutting. However, its weakness was lack of interoperability and high costs. Then in 2011 Van Hool developed the ExquiCity which was suitable for corridor transit. It has the ability to travel up to 100km on a full charge. This tram was operating across Italy, Switzerland, Germany, UK, Spain, France and also entered the Australian market through a relationship with the Transit Australia Group TAG. Later in 2017, Iriza was launched with a stylish appearance featuring more glass and chrome edge around the body and was able to run 200km range on a charge. In 2018 the ART Autonomous rapid rail transit vehicle started its operations in China with fully autonomous commands from both a control centre and guidance from on board sensors as well as GPS, Lidar systems and cameras enabling it to fully a painted line on the road with millimetre accuracy (Bodhi Alliance, 2018; Newman, Mouritz, et al., 2018 a & b).

These Trackless Tram systems are considerably cheaper than light rail with the Chinese ART estimated at $3-4m per km plus whatever road works are needed to enable a separated lane; this compares with a minimum $50m per km for light rail and up to $175m per km for the Sydney LRT.

In advancing the Trackless Tram journey it is critical to meet the interoperability requirements in any urban system and to ensure that implementation would not be limited to any one supplier. With increasing attention on local shared mobility systems that can broaden catchment areas and limit parking spaces, TTS is a potential game changer for creating better urban regeneration through integrated transit, finance and land development. The question then is where a Trackless Tram System is best able to be deployed and how best to approach urban regeneration within that corridor as the station precincts become critical to how such a TTS system can be funded and how effective it is at getting people out of cars as well as providing high quality urban outcomes in all aspects of urban development. The next section uses Urban Fabric Theory to create some perspectives on this question.

Table 2: Examples of the evolution of trackless trams

Year	Type and link	Manufacturer	Countries of operations	Key features commentary	Indicative Image
2001	Guided light rail tram	Bombardier Transportation	France	▪ Rail guided by a single central rail ▪ System costs, reliability and maintenance issues. ▪ Too fewer vehicles to serve the demand.	 Source: Berthold Werner, License https://en.wikipedia.org/wiki/en:Creative_Commons
2007	Tramways on tyres	Translohr	France, Columbia, China, Italy	▪ Modular design with between 2 and 7 carriages. ▪ Narrow vehicle permanently fixed to guide rails ▪ Cannot divert, similar to traditional steel-wheeled rail vehicles. ▪ Lack of interoperability, and expensive to build and maintain.	 Source: William Crochot, License https://en.wikipedia.org/wiki/en:Creative_Commons
2011	Bus Rapid Transit	Van Hool	Italy, Switzerland, Germany, UK, Spain, France, Luxemburg, Sweden, Norway, French Antilles and Austria	▪ Similar to light rail regarding comfort, smoothness, and stylishness though without a full optical guidance system. ▪ A range of propulsion systems: fully electric trolley, on-board systems, hybrid gas electric, gas and hydrogen fuel cell technology.	 Source: Author, Verschuer
2017	ie Tram	Irizar	Spain	▪ More glass for the carriages ▪ Chrome edge around the body for a stylised appearance. ▪ 200km range on a single charge	Source: Author, Verschuer 

2018	Autonomous Rail Rapid Transit (ART)	CRRC Zhuzhou Institute Co Ltd	China	▪ Resembles a rubber-tyred tram, but with flexibility to move around like a normal articulated bus. ▪ Autonomous rapid rail transit vehicle fully autonomous and bi-directional. ▪ Composed of individual, fixed sections joined together by articulated gangways ▪ Well developed optical guidance system	Source: Author, Verschuer 

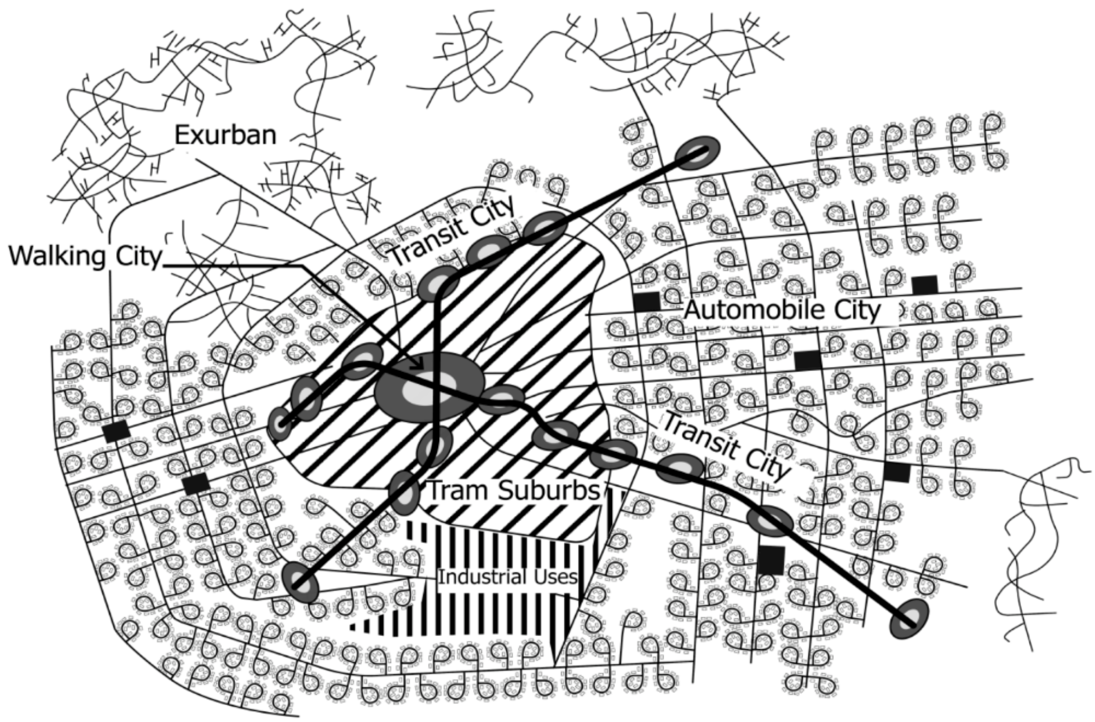
Source: Source: Caldera et al., (2019) p30.

Urban Fabric Theory

Each urban fabric consists of a particular set of spatial relationships, typology of buildings and specific land use patterns that are based on their transport infrastructure priorities (Newman et al., 2016; Thomson & Newman, 2018). Figure 1 presents the original typologies; Figure 2 shows the overlapping nature of these three fabrics.

The urban fabrics of any city can be visualised through maps based on historical development patterns. The fabrics can be defined and understood by the qualities of historical transport systems in the fabrics that have created the daily travel time budgets of the inhabitants as outlined below and the resulting properties of the three fabrics are presented in Tables 3 and 4.

Figure 1: The urban fabric typologies



Source: Author, Newman

Walking urban fabric

Walking cities have a long history as it was the only form of transport available in the majority of historical settlements to enable people to move from one place to another. Walking cities were dense (usually over 100 people per hectare), with mixed-use areas with narrow streets and this fabric remains in the old parts of cities. Most global cities attempt to retrieve the intense urban activity and fine-grained street patterns associated with walkability in their city centres but have realised that they have to adhere to the urban fabric of the walking city areas. The building of new walking urban fabric in other parts of polycentric cities is now also firmly on the planning agenda due to its economic attractions (Florida, 2010; Kenworthy & Newman, 2015; Newman & Kenworthy, 2011).

Transit urban fabric

The transit urban fabric since 1850 was originally based on trains and then trams. Both trams and trains could travel faster than walking; trams with average speeds of around 10-20 km/h and trains at around 20 – 40 km/h. This created opportunities for cities to spread out in two ways with trams forming the urban fabric of the inner transit city 10-20 kilometres across. Trams created linear development, and trains created dense nodal centres with mixed land uses along corridors (Newman et al., 2016; Thomson & Newman, 2018). Many cities are trying to enhance their transit fabric and extend it into new areas lacking transit.

Figure 2: Walking, transit and automobile city a combination of three overlapping systems

Source: adapted from Kosonen, (2013)

Automobile urban fabric

With the emergence of roads and parking for automobiles, trams were often replaced by buses, supplementing car use and resulting in low density urban sprawl. Automobile Cities from the 1950s onward could spread to some 80 km diameter in all directions, and at low density because automobiles could average 50-80 km/h while traffic levels remained low. Ultimately such areas became the basis of automobile dependence (Newman & Kenworthy, 1989) and automobility (Urry, 2004). These are the fabrics where many urban planners, developers and communities are wanting better transit, better local services and jobs and even more affordable higher density housing options, especially in declining middle suburbs (Thomson & Newman, 2018). This requires a combination of transit and urban regeneration.

The importance of regenerating and creating more walking and transit fabric in cities is that this fabric is considerably reduced in its metabolism (less resource consumption and associated waste) as well as having greater opportunities for knowledge economy jobs (Florida, 2010; Thomson & Newman, 2018). Thus Tables 3 and 4 summarise these urban fabric qualities.

Table 3: Urban Fabric elements within a city (walking/ transit/ automotive)

Urban Fabric Element	Walking City	Transit City	Automotive City
1. Street Widths	Narrow	Wide enough for transit	Wide enough for cars/trucks
2. **Squares and Public spaces**	Frequent as very little private open space	Less frequent as more private open space	Infrequent as much greater private open space
3. Street furniture	High level for pedestrian activity	High level for transit activity (bus stops, shelters)	High level for car activity (signs, traffic lights)
4. Street networks	Permeable for easy access; enables good level of service for pedestrians	Permeable for pedestrians, networks to reach transit stops, corridors enable good levels of transit service	Permeability less important, enables high levels of service for cars on freeways, arterials and local roads. Bus circulation often restricted by cul-de-sac road structure.
5. Block scale	Short blocks	Medium blocks	Large blocks
6. Building Typologies	High density minimum 100/ha usually	Medium density minimum 35/ha usually	Low density <35/ha, often much less than 20/ha.
7. Building set backs	Zero set backs	Setbacks minimal, for transit noise protection and more space	Setbacks large for car noise protection and extra space
8. Building Parking	Minimal for cars, seats for pedestrians, bike racks	Minimal for cars, seats for pedestrians, often good bicycle parking	Full parking in each building type
9. Level of service for transport mode	Pedestrian services allow large flows of pedestrians	Transit services allow large flows of transit users	Car capacity allows large flows of cars

Source: Newman et al., (2016) pp429-458.

Table 4 highlights how they can be regenerated and how old walking and transit fabrics can be built into new areas now that some fundamental problems are being found with building a city-region just with automobile urban fabric (Newman et al., 2016).

Table 4: Fabric qualities across the urban fabric elements

Urban Fabric Element	Walking City	Transit City	Automotive City
1. Urban form qualities			
▪ Density	High	Medium	Low
▪ Mix	High	Medium	Low
2. Transport qualities			
▪ Car ownership	Low	Medium	High
▪ Level of service	High l.o.s for pedestrians	High l.o.s. for transit users	High l.o.s. for car users
▪ Transport activity	High ped activity	High transit activity	High car activity
3. Economic qualities			
▪ Infrastructure costs per capita	Low - Medium	Medium - Low	High
▪ Gross domestic product per capita	High	Medium	Low
▪ Labour intensity	High	Medium	Low
4. Social qualities			
▪ Difference between rich and poor	Low	Medium	High
▪ Ability to help car-less	High	Medium	Low
▪ Health due to walking	High	Medium	Low
▪ Social capital	High	Medium	Low
▪ Personal security	Variable	Variable	Variable
▪ Traffic fatalities	Low	Low	Medium to High
5. Environmental qualities			
▪ Greenhouse gases and oil per capita	Low	Medium	High
▪ Waste per capita (buildings, households)	Low	Medium	High
▪ Footprint per capita	Low	Medium	High

Source: Newman et al., (2016) pp429-458.

Emergent principles for an urban regeneration centres framework

Seven emergent principles for creating quality urban centres around a Trackless Tram have been developed from the SBEnrc project on Australian cities along with a range of urban design and infrastructure or urban development practices used to achieve these principles. These are presented below in Table 5.

Table 5: Framework for Regenerating Urban Centres with core design/planning practices

Core Principles	Core Practices
1. **Precinct safety and accessibility** The development should be safe and healthy for people waiting to access transport nodes	▪ Human centred design ▪ Walkable urban design ▪ Place and movement design
2. **Carbon neutral - positive approach** The development should aim for carbon positive, being at least zero carbon, in both power and transport	▪ Solar passive design ▪ Solar active design ▪ Carbon neutral analysis
3. **Local shared mobility** The development should encourage diverse local modal services to access the transit service, with defined spaces	▪ Local mobility design ▪ Feeder transport design ▪ Mobility as a service
4. **Property diversity** The density and urban mix should contribute to urban regeneration	▪ Community engaged planning ▪ Agglomeration economy analysis ▪ Financial modelling
5. **Property affordability** The development should include diverse property options to provide affordable living as well as affordable housing	▪ Social housing analysis ▪ Life cycle assessment ▪ Sustainability operational analysis
6. **Nature-loving and biodiverse spaces** The development should include and connect biophilic and biodiverse greenspaces, supporting endemic species and habitat	▪ Biophilic design ▪ Water sensitive design ▪ Landscape oriented design
7. **Inclusive, integrated, place-based planning** Planning, design and implementation (operation, maintenance) should involve diverse stakeholders and all tiers of government to provide an integrated place-based approach.	▪ Joined up governance analysis ▪ Partnership analysis ▪ Procurement options analysis

Source: Caldera et al., (2019) p11.

The Framework for Urban Regeneration of Centres and its Application to Urban Fabrics

In Table 6 below, the seven core principles are applied to four kinds of urban fabrics that are relevant to the case studies in the SBEnrc research. The routes in all four cities: Townsville (from CBD to James Cook University and Health Campus), Sydney (from Liverpool CBD to new Badgerys Creek Airport), Melbourne (City of Wyndham with need for links to heavy rail and for new urban centres), Perth (five local governments from Canning through the CBD to Stirling). All but two of the case studies go through a central area walking city, all but two go through an inner city transit fabric that has been defined by a previous tramway, all have a middle suburb with potential for transit fabric as the only redevelopment is backyard infill that is failing to provide a centre with transit, and all have an outer suburb automobile fabric area with the need for a centre and transit.

Table 6: The Framework applied to four different urban fabrics.

Core Principles/ Urban Fabric Examples	Central City Walking Fabric (current rail-based centre)	Inner City Transit Fabric (old tram line area)	Middle Suburb Transit Fabric (infill failing)	Outer Suburb Automobile Fabric (new area needing a centre)
1. Precinct safety and accessibility	Walkability the critical value	Walkability in centre and corridor access both critical	Walkability in centre and corridor access both critical	Walkability in centre and corridor access both critical
2. Carbon neutral – positive approach	Strong transport carbon reductions but harder to do solar on buildings	Easier to do solar on buildings and harder on transport carbon reductions	Easy to do solar on buildings and hard on transport carbon reductions	Very easy to do solar on buildings and much harder on transport carbon reductions
3. Local shared mobility	Essential character	Essential character	Essential character	Essential character
4. Property diversity	Essential character	Essential character	Essential character but markets harder on mixed use	Essential character but markets hard on mixed use
5. Property affordability	Important but more difficult	Important but still difficult	Important and easier to achieve	Important and easier to achieve
6. Nature oriented space	Critical with emphasis on biophilic buildings and small pocket parks	Critical with emphasis on biophilic buildings, small pocket parks and green corridor	Critical with emphasis on biophilic buildings, small pocket parks and green corridor	Critical with emphasis on small pocket parks, green corridor and landscape-oriented development
7. Inclusive, integrated, place-based planning	Essential for delivery	Essential for delivery	Essential for delivery	Essential for delivery

Source: Caldera et al., (2019) p26.

The main conclusions from this analysis are that Trackless Trams could provide a major design solution for each of the four urban fabrics examined. However, the differences in urban fabric are considerable and significant so they do need to be addressed separately. They will need to have specific design issues resolved for each area as summarised below:

1. Walkability for safety and accessibility is the critical value in all four fabrics. High quality corridor transit is the extra critical accessibility component in the fabrics outside of the central city. This is a global issue where a Trackless Tram may be a significant opportunity as a connector down corridors or to heavy rail lines enabling a much better transit network quality.

2. Carbon neutral or carbon positive is easier the closer to the city centre as there is much less car dependence, but the extra space associated with lower density outer area fabrics is easier for solar on buildings; this trade-off can be managed to achieve carbon neutral in all fabrics but needs different kinds of technologies and investments (Newton & Newman, 2013).

3. Local shared mobility is essential in all four fabrics to manage the need for parking, for equity reasons and for transit support (Glazebrook & Newman, 2018); managing how to enable this along with walkability is a new design challenge as new evidence is showing that Uber and autonomous vehicles are increasing VKT not decreasing it as suggested by branding (Schaller, 2018).

4. Property diversity is also an essential character in each fabric though achieving mixed land use becomes harder with distance from the central city area due to the density levels required to achieve market viability, and the prevalence of single-use residential zoning and minimum parking requirements.
5. Property affordability is important to seek in all urban development not just low density areas on the urban fringe but this becomes easier to achieve the further away from the city centre.
6. Nature-oriented space is also a critical element of all fabrics as it is an essential part of human health and planetary health, but varies in its spatial definition from intensively building-oriented biophilics in the walking city supplemented with small pocket parks, to an emphasis on how the transit corridor is greened, then more and more landscape-oriented design as the fabric has less spatial intensity (Desha et al, 2016).
7. The integration of each of the other six core principles into a final design, procurement and delivery process that has place as its core focus, is essential for each urban fabric. This will require changes to governance systems that can enable inclusive, integrated, place-based planning.

Conclusions

The future of urbanism in Australia and around the globe to adapt and respond to the big challenges of climate change, economic development and social inclusion, will depend on how well we do urban regeneration and create new urban centres in the suburbs. This paper has built on the need for improved urban regeneration and urban centre-building in Australian cities to be linked to the need for improved transit systems and particularly Trackless Trams. An analysis based on the Theory of Urban Fabrics and a Framework for Urban Regeneration involving seven principles, has created some approaches to how well Trackless Trams can assist with urban regeneration. The Framework has been applied to four different urban fabric types, based on the fabrics in the four case studies being studied as part of the SBEnrc project. The differences in the fabrics are considerable thus requiring significant attention to specific design policies, however the overall need for better transit and more urban regeneration is clear in all areas. In each case the urban regeneration centres will not emerge unless they have a quality transit corridor that can reduce car dependence, nodes at stations which emerge from redevelopment opportunities, and place-based design that can make the most of the amenity needed to create value along the whole corridor. In other words, the urban regeneration and the new transit system must be done together.

The approaches to integrating transit and urban regeneration will differ in different parts of the city. Each area has a different urban fabric that requires its features to be recognised and respected before designing solutions. The seven principles created to help with this design process seem to have some ability to help in this process; all have relevance to each site and some need to be very specifically oriented to accommodate the differences in urban fabric quality. Delivering such different urban design qualities along a new transit corridor or in an old main street remains a major challenge for designers, planners and engineers to work out with politicians, developers, financiers and community leaders. The planning governance systems in Australian cities will be tested for their flexibility and relevance to enable the range of private investment to be involved and will require significant levels of partnership to be developed to enable inclusive, integrated, place-based fabrics in each part of the city.

References

Bodhi Alliance, (2018) *Trackless Trams in Perth: From Concept to Reality*, Bodhi Alliance, Perth.

Caldera, S., Desha, C., Reid, S., Newman, P. and Mouritz, M. (2019) Sustainable Centres of Tomorrow: Principles and Practices - Report for Project 1.62 Sustainable Centres of Tomorrow: People and Place, Sustainable Built Environment National Research Centre.

Desha, C., Chenoweth Reeve, A., Newman, P., Beatley, T., (2016) Urban nature for resilient and liveable cities, *Smart and Sustainable Built Environment,* Vol. 5: 1 pp.1-4

Florida, R. (2010). *The great reset: How new ways of living and working drive post-crash prosperity*. Toronto: Random House Canada.

Glazebrook, G., & Newman, P. (2018). The city of the future. *Urban Planning, 3*(2), pp.1-20.

Kosonen, L. (2013). Model of Three Urban Fabrics: Adapted for Finnish Intermediate Cities. A web-based document http://urbanfabrics.fi/. The Finnish Environment Institute. Acessed 9 June 2020.

Newman, P., Davies-Slate, S., & Jones, E. (2018). The Entrepreneur Rail Model: Funding urban rail through majority private investment in urban regeneration. *Research in Transportation Economics, 67*, pp.19-28.

Newman, P., Hargroves, K., Davies-Slate, S., Conley, D., Verschuer, M., Mouritz, M., & Yangka, D. J. J. o. T. T. (2018). The Trackless Tram: Is It the Transit and City Shaping Catalyst We Have Been Waiting for? *Journal of Transportation Technologies, 9*(1), pp.31-55.

Newman, P., & Kenworthy, J. (2011). 'Peak car use': understanding the demise of automobile dependence. *World Transport Policy & Practice, 17*(2), pp.31-42.

Newman, P. & Kenworthy J. (2015). *The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning*. In. Washington, DC.: Island Press

Newman, P., Mouritz, M., Davies-Slate, S., Jones, E., Hargroves, K., Sharma, R., & Adams, D. (2018a). Delivering Integrated Transit, Land Development and Finance – a Guide and Manual: with Application to Trackless Trams. Sustainable Built Environment National Research Centre, Curtin Univeristy, Perth. https://sbenrc.com.au/app/uploads/2018/10/TRACKLESS-TRAMS-MANUAL-GUIDE_email.pdf

Newman, P., Mouritz, M., Davies-Slate, S., Thomson, G., Sharma, R., Dia, H., & Hargroves, K. (2018b). Integrated Cities: Procuring Transit Infrastructure through Integrating Transport, Land Use and Finance. Sustainable Built Environment National Research Centre, Final Industry Report, Project 1.55 August. https://sbenrc.com.au/app/uploads/2019/01/IntegratedCities_1.55_IndustryReport_WEB.pdf

Newman, P. G. & Kenworthy, J. R. (1989). *Cities and automobile dependence: An international sourcebook*: Gower Technical.

Newton, P. & Newman, P. (2013) The Geography of Solar PV and a New Low Carbon Urban Transition Theory, *Sustainability* 5(6): pp.2537-2556.

Schaller, B. (2018) *The New Automobility: Lyft, Uber and the Future of American Cities,* Schaller Consulting, New York.

Thomson, G., & Newman, P. (2018). Urban fabrics and urban metabolism–from sustainable to regenerative cities. *Resources, Conservation and Recycling, 132*, pp.218-229.

Urry, J. (2004). The 'system'of automobility. *Theory, Culture & Society, 21*(4-5), pp.25-39.