Trackless Trams in Perth
Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) Report

A report as part of the Perth Continuum Case study

Research Project No SBEnrc 1.62 Sustainable Centres of Tomorrow: People and Place

January 2020

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Dr Jan Scheurer, Centre for Urban Research, RMIT University and Urbanet/CUSP, Curtin University

EXECUTIVE SUMMARY

This component of the *SBENRC 1.62: Sustainable Centres for Tomorrow* project assesses proposals for an initial Trackless Tram corridor and medium-term Trackless Tram target network in inner Perth with regard to spatial accessibility across the multimodal public transport network in the context of urban intensification opportunities created by the new public transport infrastructure.

An initial stakeholder workshop in October 2019 resulted in three proposals for route variations of a 30-km diametrical Trackless Tram line linking Scarborough Beach and Cannington via central Perth and Curtin University (Options 1, 2 and 3). A fourth route variation (Option X) along the same corridor was added by the project team after the first three options had been assessed, in order to further optimise its performance. After further consultations with political decision makers, it was decided to also assess two route options for a shorter (16 km) radial Trackless Tram corridor connecting Burswood and central Perth with the Morley-Embleton area (Options 4 and 5).

Using the Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) tool for a comprehensive accessibility assessment, it is shown that each of the six options improves public transport movement options across inner Perth and addresses mounting capacity problems on the bus system, if to varying extent.

A Trackless Tram CBD alignment along St Georges and Adelaide Terrace in conjunction with the transformation of some or most south-eastern radial bus routes into rail and Trackless Tram feeders at Burswood and Victoria Park (Options 1, 2, 4, 5 and X) will improve the efficiency and legibility of

the CBD network and free up buses to be redeployed for better service frequencies and additional orbital bus lines elsewhere in inner Perth.

Continuing the Trackless Tram CBD alignment west along St Georges Terrace through West Perth and Leederville (Option X) has a more beneficial overall network effect and frees up more buses for other services than alternative alignments through Northbridge and North Perth (Options 1, 2 and 3). However, since the first Trackless Tram route would bypass Perth Central station in this scenario, two contrasting effects can be expected: Trains on the CBD approaches will experience some relief from mounting congestion, while congestion on buses particularly along Wellington Street may further deteriorate.

In a further step, proposals for targeted residential and employment growth in selected hubs along the Trackless Tram alignment were included in the analysis. It is shown that the viability of a medium-capacity public transport system is already established along its CBD section and Swan River crossing into Victoria Park without additional land use intensification. In the Glendalough-Stirling, Bentley-Curtin University and Carousel-Cannington areas, significant residential and employment growth over and beyond the 2031 trend is required to justify the added capacity and required infrastructure investment of a Trackless Tram. A further branch line between Curtin University and Canning Bridge station can further add to this rationale and greatly improve network connectivity in the inner south.

A second workshop in December 2019 motivated participants to think a step further and identify how the previous scenarios' shortfalls can be resolved by a longer-term network vision. Two further scenarios were constructed from this process. A combination of Options 4 and X generates a five-line network (Option Y) that maintains and extends the efficiency benefit of an east-west through route along the CBD Terraces while adding a link into and beyond Perth Central station to Morley. In a final scenario, an additional CBD Trackless Tram corridor along Wellington Street and a branch from West Perth to UWA were included (Option Z), creating a six-line network and allowing for the removal and redeployment of all Causeway bus routes. This scenario is the best performer on all SNAMUTS indicators including resilience (congestion relief), and can be considered a draft for a medium-term Trackless Tram target network in inner Perth.

SECTION 1
Introduction

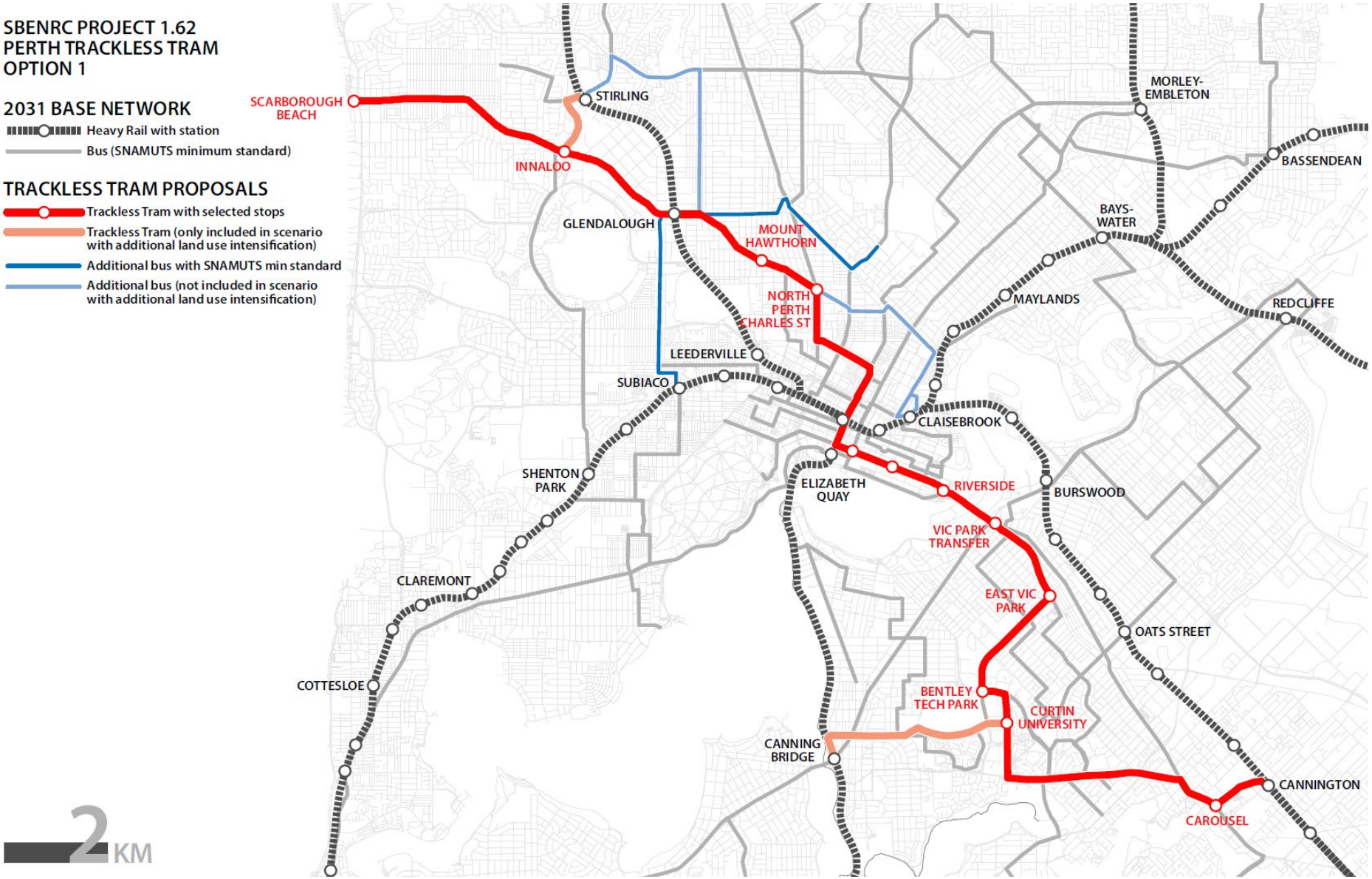
This component of the *SBENRC 1.62: Sustainable Centres for Tomorrow* project assesses proposals for an initial Trackless Tram corridor and medium-term Trackless Tram target network in inner Perth with regard to spatial accessibility across the multimodal public transport network, and identifies the urban intensification capacity window that makes the introduction of a medium-capacity public transport mode imperative along these corridors.

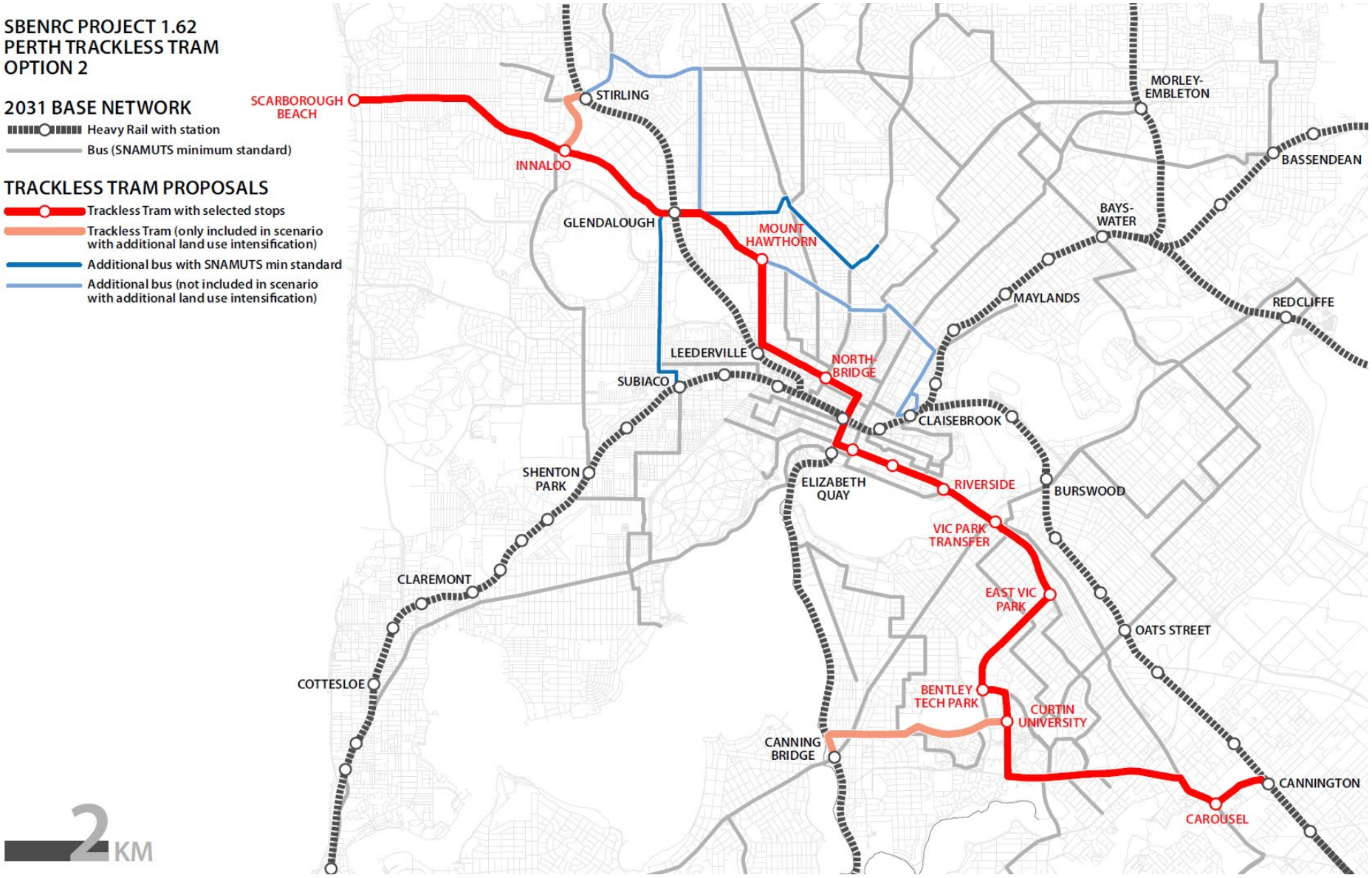
The accessibility assessment utilises the Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) tool[1] to quantify and visualise the added value of a Trackless Tram corridor for metropolitan Perth's public transport system as a whole. The urban intensification capacity assessment is derived from the SNAMUTS analysis and will assist project proponents in identifying minimum targets for additional residents and jobs in the catchment areas of corridor nodes to inform joint development decisions and value capture funding mechanisms.

A stakeholder workshop held in October 2019 served to determine input for the SNAMUTS tool concerning alignment details, operational performance (commercial speed and frequencies), network integration/adjustments and interoperability of Trackless Trams with the existing public transport system. It resulted in the identification of three variations on a starter line in inner Perth (see Figures 1-3):

Figures 1-3: *Overview of route variations for a Trackless Tram starter line in Perth (Options 1, 2 and 3)*

[1] See www.snamuts.com for a detailed description of the SNAMUTS tool


SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION 1
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Trackless Tram (only included in scenario with additional land use intensification)
Additional bus with SNAMUTS min standard
Additional bus (not included in scenario with additional land use intensification)
SCARBOROUGH BEACH
STIRLING
INNALOO
GLENDALOUGH
MOUNT HAWTHORN
NORTH PERTH CHARLES ST
LEEDERVILLE
SUBIACO
SHENTON PARK
CLAREMONT
COTTESLOE
CANNING BRIDGE
ELIZABETH QUAY
CLAISEBROOK
RIVERSIDE
VIC PARK TRANSFER
EAST VIC PARK
BENTLEY TECH PARK
CURTIN UNIVERSITY
CAROUSEL
CANNINGTON
OATS STREET
BURSWOOD
MAYLANDS
BAYS-WATER
MORLEY-EMBLETON
BASSENDEAN
REDCLIFFE
2 KM


SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION 2
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Trackless Tram (only included in scenario with additional land use intensification)
Additional bus with SNAMUTS min standard
Additional bus (not included in scenario with additional land use intensification)
SCARBOROUGH BEACH
STIRLING
INNALOO
GLENDALOUGH
MOUNT HAWTHORN
MORLEY-EMBLETON
BASSENDEAN
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BENTLEY TECH PARK
CURTIN UNIVERSITY
CANNING BRIDGE
CANNINGTON
CAROUSEL
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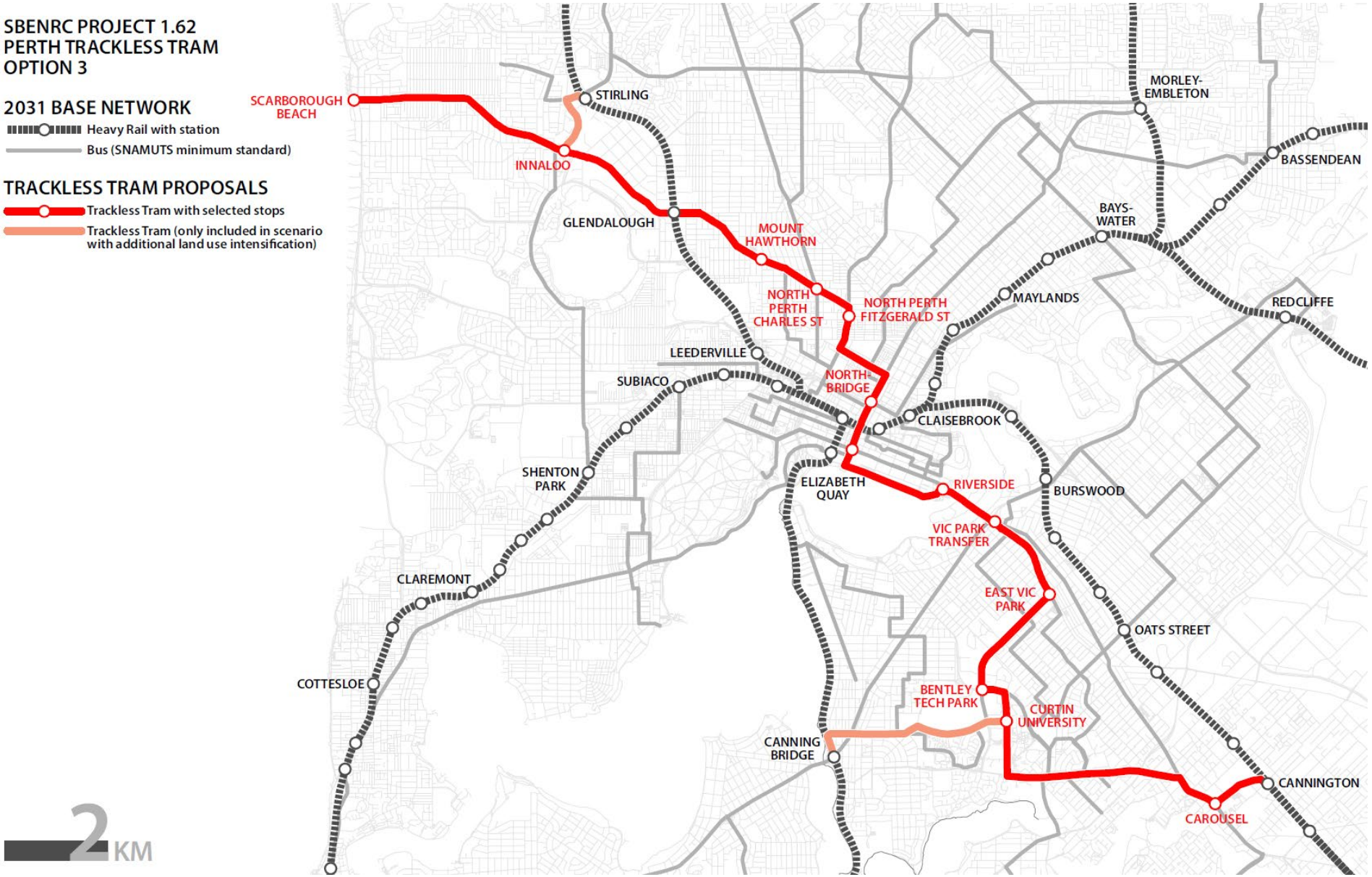
SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION 3
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Trackless Tram (only included in scenario with additional land use intensification)
SCARBOROUGH BEACH
STIRLING
INNALOO
GLENDALOUGH
MOUNT HAWTHORN
NORTH PERTH CHARLES ST
NORTH PERTH FITZGERALD ST
NORTH BRIDGE
LEEDERVILLE
SUBIACO
SHENTON PARK
CLAREMONT
COTTESLOE
ELIZABETH QUAY
CLAISEBROOK
RIVERSIDE
VIC PARK TRANSFER
EAST VIC PARK
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BAYS-WATER
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BASSENDEAN
REDCLIFFE
2 KM

- **All three options** contain segments along Scarborough Beach Road between Scarborough Beach and Mount Hawthorn (Oxford St), and between the Causeway and Cannington Station via Albany Highway, Kent Street, Curtin University campus, Manning Street, Albany Highway and Cecil Avenue.
- **Option 1** describes a route continuing along Scarborough Beach Road from Mount Hawthorn then leading through Charles Street, Bulwer Street, William Street, St Georges Terrace and Adelaide Terrace to the Causeway;
- **Option 2** describes a route continuing from Hawthorn via Oxford Street, Newcastle Street and Williams Street to St Georges Terrace, Adelaide Terrace and the Causeway;
- **Option 3** describes a route continuing along Scarborough Beach Road from Mount Hawthorn via Angove Street, Fitzgerald Street, Bulwer Street, Beaufort Street and Barrack Street to then reach the Causeway via Riverside Drive and Terrace Road.
- **All three options** contain assumptions about bus network adjustments. Trackless Trams will replace buses on routes 34 and 100 (between Curtin University and Cannington), 960 (between Perth Central and Curtin University) and 990 (full length). In Options 1 and 2, the bus lines currently operating along Adelaide and St Georges Terrace will be rerouted partly via Plain and Wellington Street (to Perth Central), and partly via Riverside Drive/Terrace Road (to Elizabeth Quay) in order to avoid mixed operation between buses and Trackless Trams on these busy CBD corridors.
- **Options 1 and 2** result in a net saving of public transport vehicles over the 2031 Trend network: more buses are replaced than Trackless Tram vehicles required as a result of higher speeds and the opportunity to reduce the (very high) frequency of buses in the CBD in favour of larger Trackless Trams. To keep the total vehicle input in our assessment constant across all scenarios, these excess buses are assumed to be redeployed into frequency improvements on existing bus routes and/or into the establishment of additional high-frequency orbital bus routes designed to support the Trackless Tram corridor as feeders and distributors. In Option 3, no net saving of public transport vehicles can be achieved and hence, no additional orbital bus routes feature in that scenario.

In the following section of this report (Section 2), each of these three potential Trackless Tram starter lines will be assessed separately and comparatively towards its impact on the land use-transport system as projected for the target year 2031.

Section 3 of this report will assess three further Trackless Tram route options that emerged during stakeholder and team discussions over the previous three scenarios. Option 4 and Option 5 describe two variations of a shorter starter route linking the CBD with the Perth's inner north-eastern corridor towards Mount Lawley and Morley. Option X is a variation of Option 2 that attempts to optimise the Trackless Tram alignment in the CBD so more buses can be removed from this area, and more interchanges to rail provided.

Section 4 of this report will revisit each of the previous six options in the context of more ambitious urban intensification scenarios around the new Trackless Tram corridors. Specifically, this assessment will produce estimates to quantify the extent of land use intensification (additional residents and jobs) over and beyond the 2031 trend that is required along the Trackless Tram corridors to make the deployment of an intermediate-capacity public transport mode imperative. Or in other words: what is the threshold of population and employment concentration along these routes that would overwhelm the capacity and performance of a bus system?

The final section (Section 5) will then construct two further scenarios (Options Y and Z) based on feedback at a second stakeholder workshop held in December 2019, combining network elements and incorporating insights of the previous steps in order to construct a network vision where the Trackless Tram makes the best possible contribution to multi-modal integration and stimulation of transit-oriented land development in metropolitan Perth.

SECTION 2
Comparison of Options 1, 2 and 3

This section assesses the accessibility performance of each of the three options for a Trackless Tram starter line shown in Figures 1-3, against a land use and public transport network projection for the target year 2031.

These projections are based on detailed residential population and employment forecasts from the Western Australian Strategic Transport Evaluation Model (STEM), and the Metronet strategy for medium-term expansion of Perth's heavy rail network.

The projections assume that weekday daytime frequencies on all metropolitan rail lines are improved from the current typical 15-minute intervals to 10 minutes. On some inner sections and where several lines overlap, rail frequencies are further improved to every 5 or 3 1/3 minutes. Ten-minute daytime intervals are also assumed to apply across the high-frequency bus network by 2031, including the Circle Route.

Travel times on both Perth's rail and bus routes are assumed to remain unchanged over the status quo (2016), except where additional stations are expected to be added to existing rail lines.

Trackless Tram services in each of Options 1, 2 and 3 are assumed to be characterised by:

- daytime service frequencies between every 6 2/3 minutes (Options 1 and 2) and every 7 1/2 minutes (Option 3);
- a vehicle capacity of 180 passengers, equivalent to a contemporary light rail vehicle such as Melbourne's E-class tram;
- travel times calculated on the basis of a commercial speed between 20-30 km/h, depending on the alignment type and operating environment.

In general, a 20 km/h speed assumption applies to CBD areas and activity centres with high pedestrian activity and no physical segregation of the Trackless Tram alignment from other traffic (examples: William Street, CBD or Albany Highway, Victoria Park). A 25 km/h speed assumption applies to Trackless Tram alignments with effective physical segregation from private vehicle and pedestrian traffic, but retaining frequent crossing points for both (examples: Scarborough Beach

Road, Innaloo or Adelaide Terrace, CBD). A 30 km/h speed assumption applies where the Trackless Tram has its own alignment and crossing points with other transport modes are limited and controlled (examples: Causeway or Curtin University campus). In all three cases, however, these speeds will only be achievable if Trackless Trams are prioritised at intersections throughout the route, and if vehicle intrusion, parking manoeuvres and turning movements are tightly restricted particularly where no physical segregation exists between Trackless Trams and other traffic.

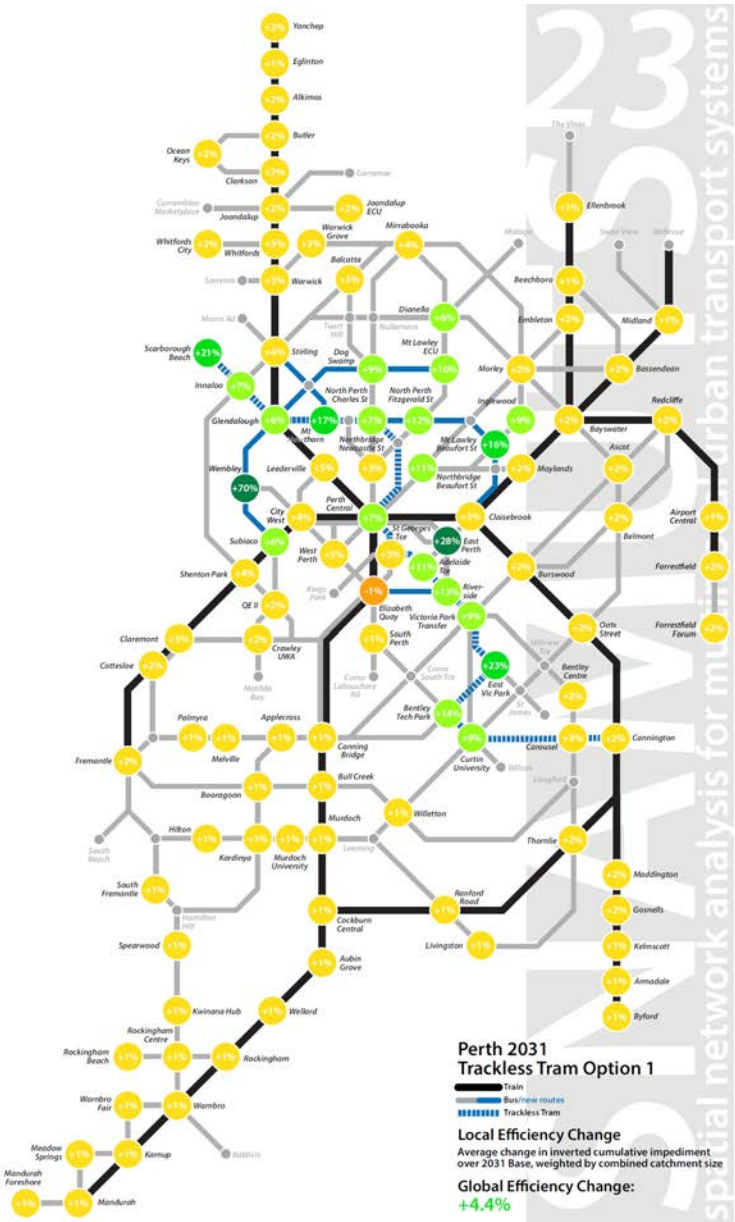
The resulting travel time assumptions for the Trackless Tram lines assessed in this section are 1 hour 13 minutes from terminus to terminus for Option 1 (29.3 km), 1 hour 12 minutes for Option 2 (29.2 km), and 1 hour 15 minutes for Option 3 (30.0 km). Average commercial speeds along the entire routes thus range between 24.0 and 24.3 km/h across the three options.

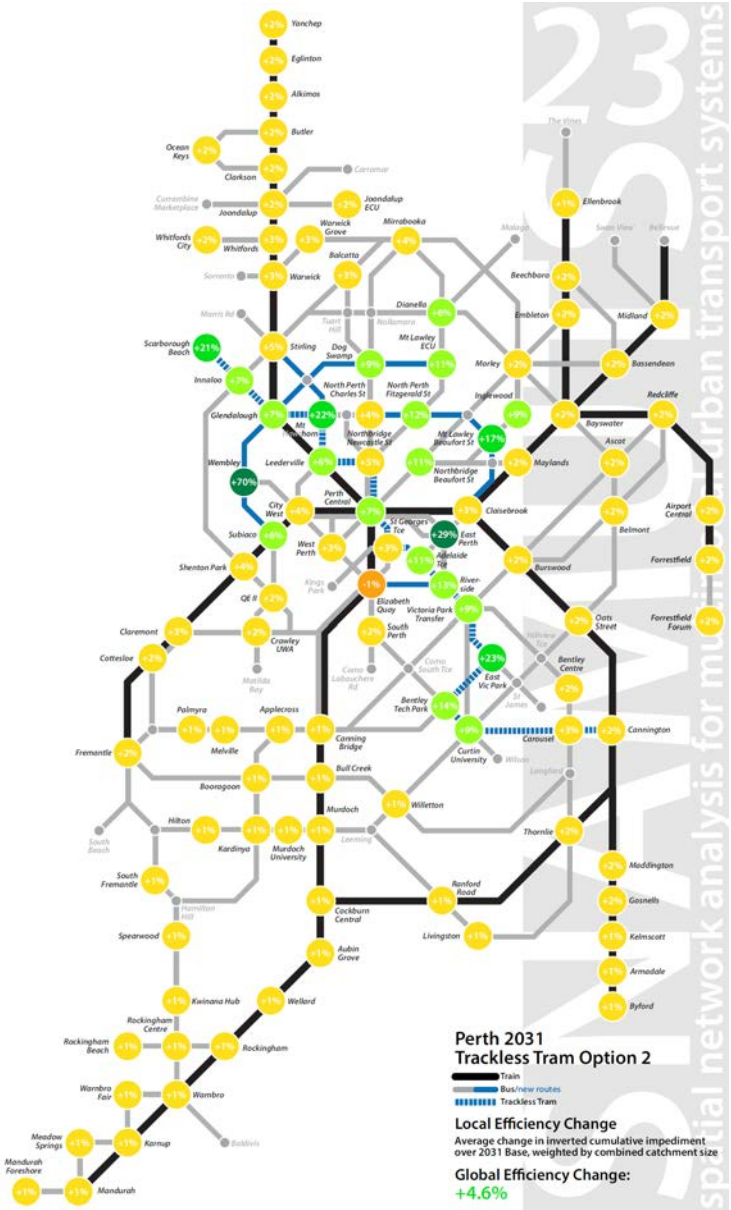
Efficiency change

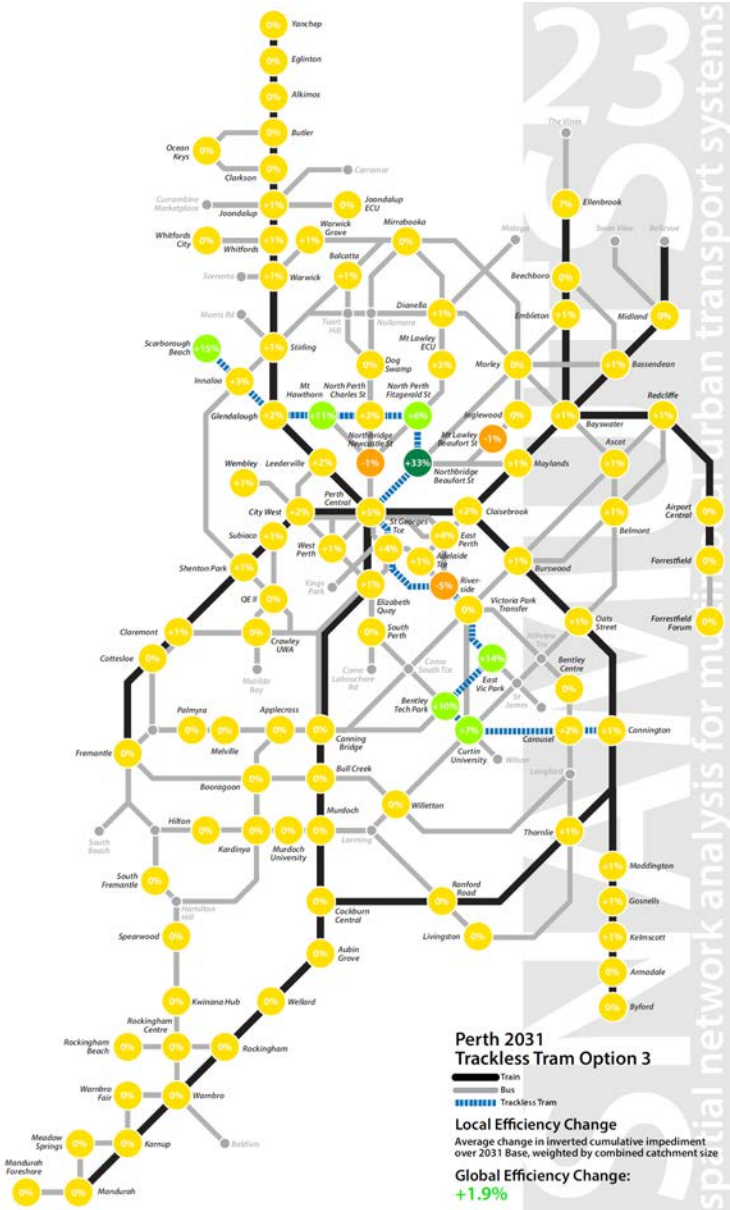
Figures 4-6 show the impact of each starter route on public transport accessibility using the SNAMUTS efficiency change index. Efficiency change uses values from other SNAMUTS indicators (closeness and betweenness) to quantify how ease of movement in relation to the land use structure changes as a result of specific infrastructure or service measures. Figures are provided across a network (metropolitan Perth), and for each of 104 activity nodes contained therein. They refer to a comparison between the network including each Trackless Tram starter line option and a base case network projection for 2031 with no Trackless Trams. The indicator is expressed as a percentage figure, with positive figures indicating an improvement and negative figures a deterioration in accessibility over the comparison case.

Figures 4-6: *SNAMUTS efficiency change network diagrams for Trackless Tram Options 1, 2 and 3 over the 2031 Trend (see Figures 1-3)*

Of the three initial options, Options 1 and 2 deliver a global efficiency improvement of 4.4% and 4.6% respectively, while Option 3 only achieves an increment of 1.9%. The key reason for this discrepancy is the greater network effect that is achieved in Option 1 and 2 by







redeploying buses saved in the CBD to new or improved orbital routes. The interplay of Trackless Trams as an intermediate mode with higher performance than the current bus routes and the creation of connecting new bus services to support this role spread a tangible accessibility benefit across much of Perth's inner north-west.

In contrast, Option 3 does not move any buses from the St Georges -Adelaide Terrace corridor (other than those immediately replaced by the Trackless Tram route) and hence does not allow for additional orbital bus routes while keeping the overall input of operational resources constant.

On most remaining SNAMUTS indicators (Table 1), a similar performance pattern is apparent. Options 1 and 2 enable better average ease of movement (closeness

centrality), a greater reduction of the need to transfer (degree centrality), a larger reach of an average 30-minute journey, a higher average concentration of travel opportunities (nodal betweenness) and better flexibility of movement (nodal connectivity) than Option 3. Only on the average resilience index does Option 3 slightly outperform Option 1 (but not Option 2).

Thus, there is merit, in accessibility performance terms, in allowing the Trackless Tram project to prompt a fundamental reorganisation of Perth's central area bus network. Options 1 and 2 move away from a singular bus trunk route along the Terraces that fans out into direct lines towards a multitude of suburban destinations, and instead distribute those buses not replaced by the Trackless Tram along two alternative corridors within the CBD (Wellington St and Riverside Drive). Option 3, in contrast, leaves the Terraces bus trunk route in place and instead diverts the Trackless Tram along Terrace Road and Riverside Drive.

In Section 3 of this report, we will take this insight one step further and construct a scenario (Option X) that will transform the majority of south-eastern radial bus routes into feeder services to the Trackless Tram and rail at Victoria Park and Burswood, and thus free up even more operational resources for additional orbital bus routes strengthening the multi-modal and multi-directional public transport network elsewhere in suburban Perth.

Table 1: *Overview of average SNAMUTS indicator results for Trackless Tram Options 1, 2 and 3, and the 2031 Trend network (without Trackless Trams)*

2031 SNAMUTS *23R*	Trend	Option 1	Option 2	Option 3
Average Closeness Centrality Metropolitan Perth	47.8	46.9	46.9	47.5
Average Degree Centrality Metropolitan Perth	1.01	0.98	0.98	0.99
Average 30-min Contour Catchment Metropolitan Perth	14.6%	15.6%	15.7%	15.0%

2031 SNAMUTS *23R*	Trend	Option 1	Option 2	Option 3
Average Nodal Betweenness Metropolitan Perth	50.8	51.5	51.7	50.9
Average Nodal Resilience Metropolitan Perth	+3.4	+5.4	+5.7	+5.5
Average Nodal Connectivity Metropolitan Perth	31	34	35	33
Global Efficiency Change Metropolitan Perth		+4.4%	+4.6%	+1.9%
Average SNAMUTS Composite Score Metropolitan Perth	19.3	20.1	20.2	19.7

Betweenness centrality

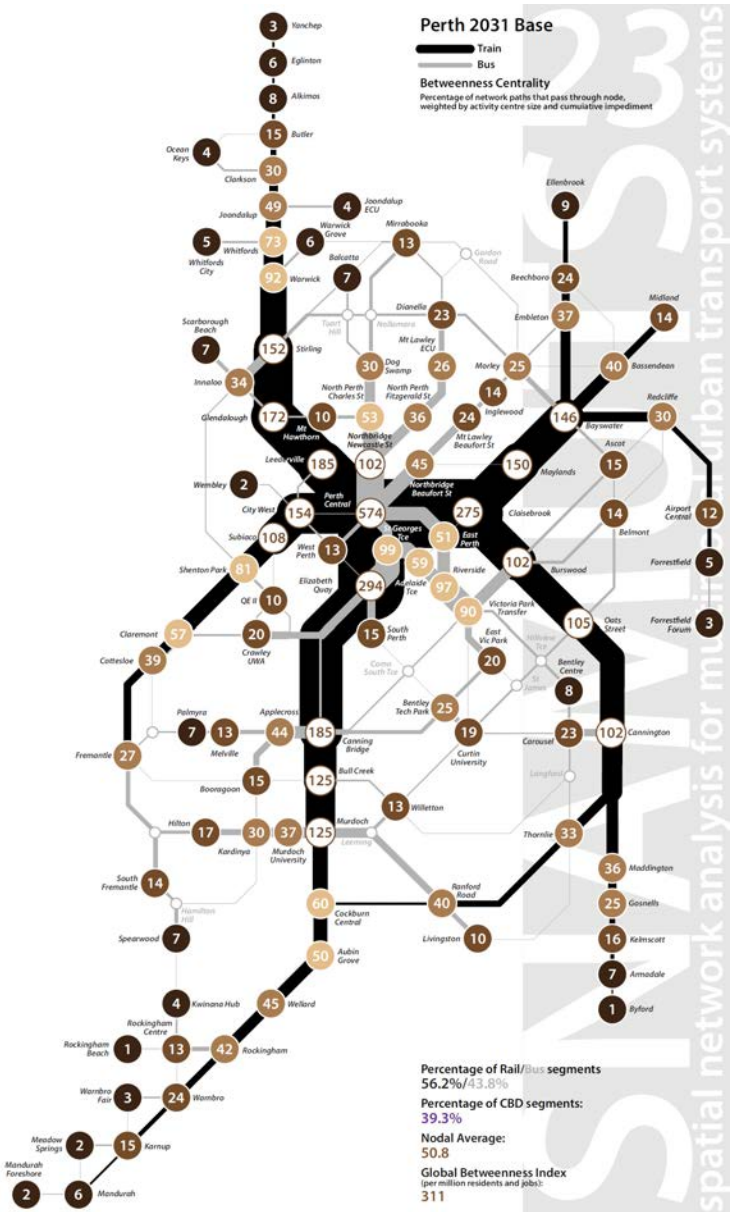
Figures 7-10 reveal greater insight into the performance of the three scenarios on the betweenness centrality index. Betweenness centrality measures the relative importance of an activity node or route segment for facilitating public transport movement across the city. It is derived from the concentration of activities at either end of each journey, and the ease of movement (closeness centrality)[2] along that journey. Higher values indicate that a reference node is located at the 'crossroads' of movement. A network is generally more balanced in operational terms, and accessibility more equitably distributed, where these values follow a smooth decay curve from more central to more peripheral locations and avoid excessive spikes in particular activity nodes or route segments, as these may be associated with congestion. In mature-sized networks, it is also beneficial

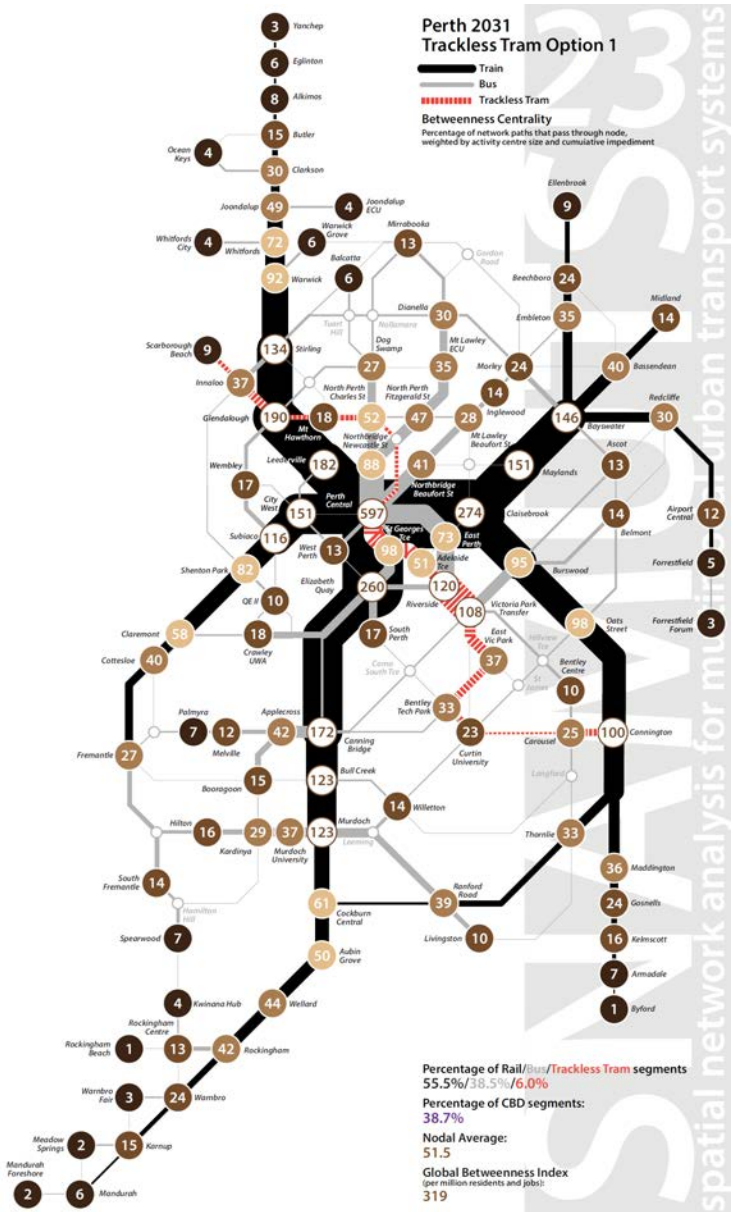
[2] Closeness centrality is based on a definition of spatial separation or travel impediment that takes in travel time and service frequency on each route segment. More information on www.snamuts.com

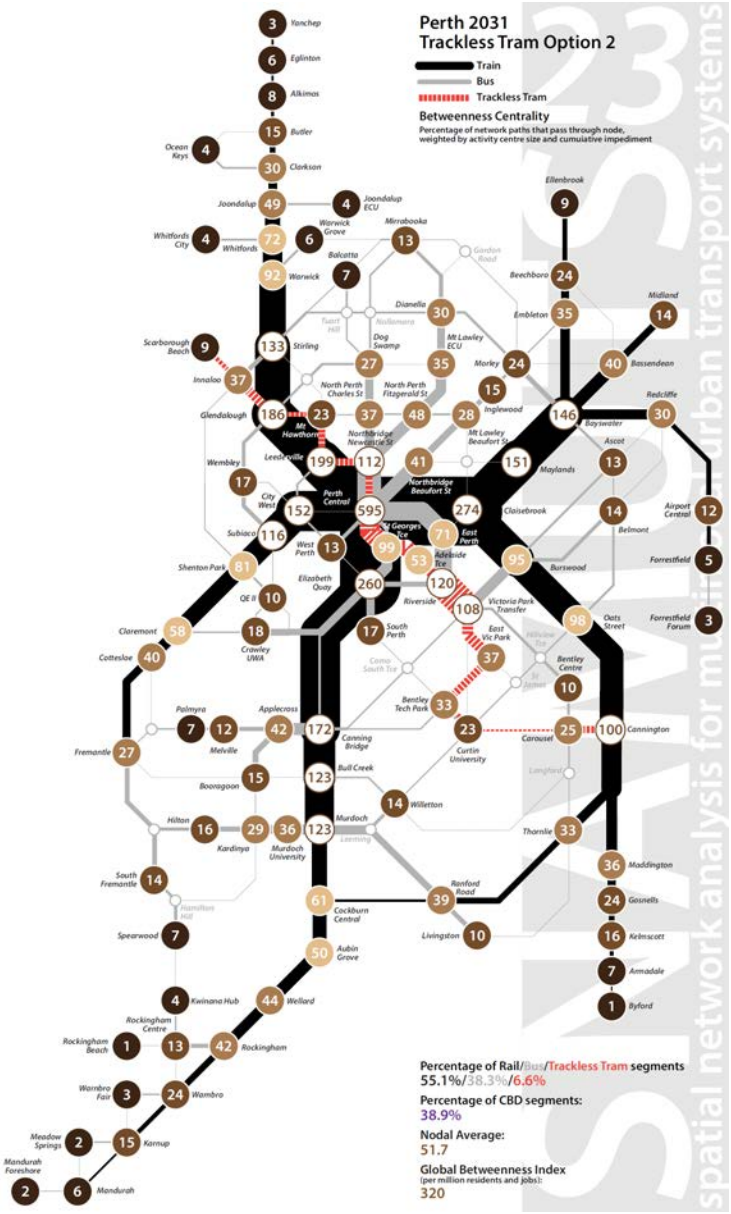
that higher-capacity modes (rail) account for a larger share of the citywide betweenness scores than lower-capacity modes (buses).

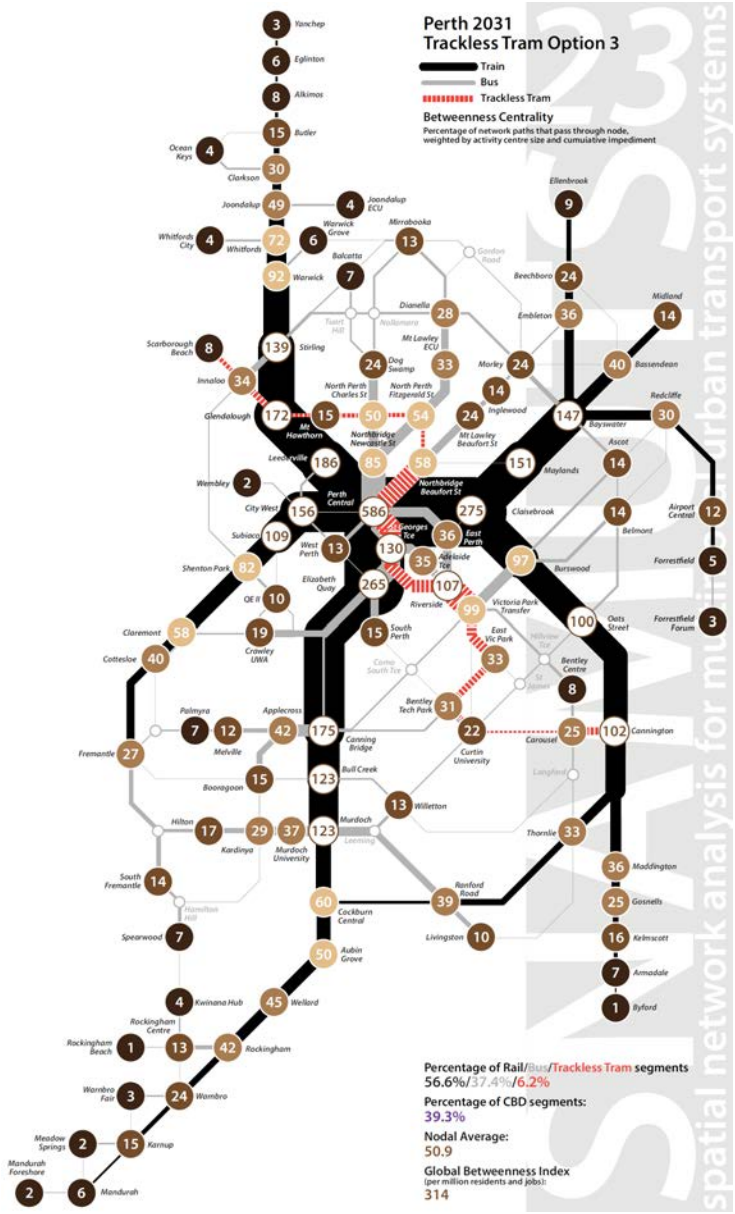
Figures 7-10: *SNAMUTS betweenness centrality index for the 2031 Trend network and for Trackless Tram Options 1, 2 and 3*

When introducing a new mode or line that is associated with significant infrastructure investment and/or intervention in existing streetscape organisation and traffic management, the salient questions this index can answer are twofold. Firstly, we would like to know whether the investment pays off in terms of the new mode or line attracting a significant number of travel opportunities generated by the land use-transport system. This tends to be the case if the new infrastructure is well-positioned among the travel flows across the network, and









provides attractive links (short travel times, high frequencies) between important places of activity. Secondly, we are interested in learning whether the new mode or line makes a contribution to relieving currently stressed parts of the network from potential congestion – or whether it actually further exacerbates these effects.

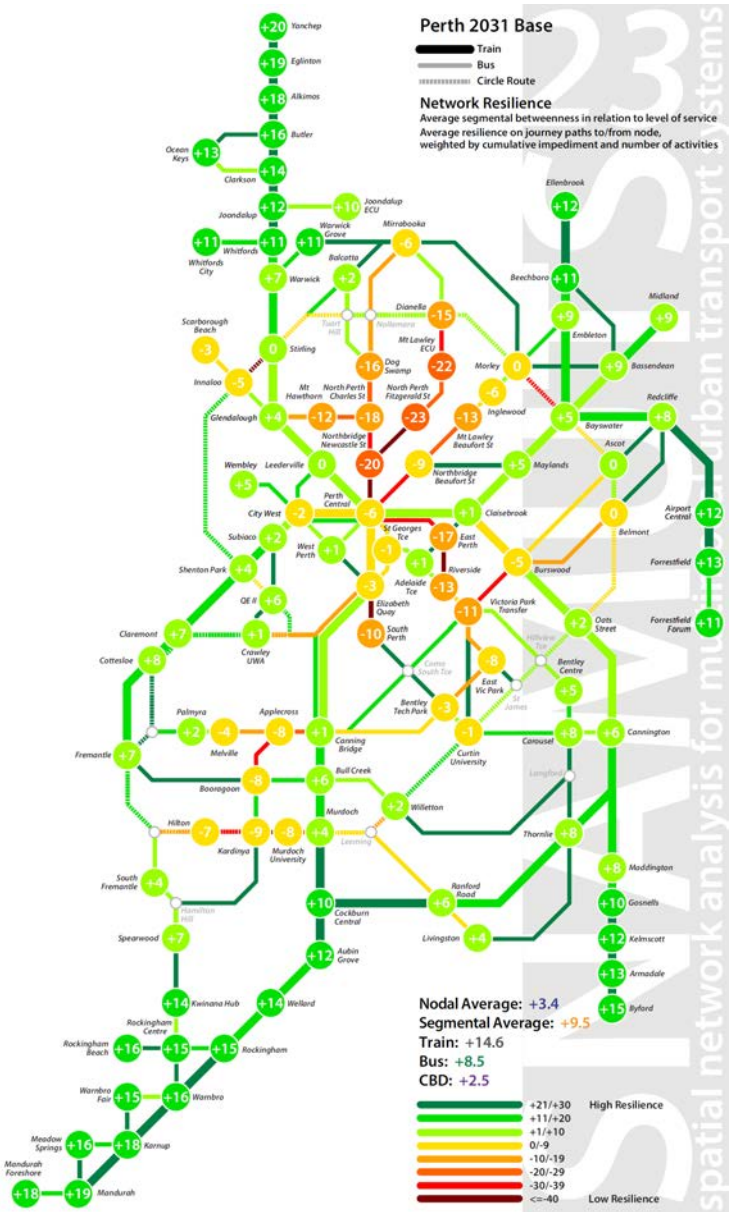
On the first question, the Trackless Tram starter line, once in operation, attracts between 6.0% (Option 1) and 6.6% (Option 2) of all public transport movement opportunities in metropolitan Perth. However, this effect is very unevenly distributed in geographical terms: While the CBD sections and the link across the Causeway show up very prominently in all three scenarios, there are also several weak links,

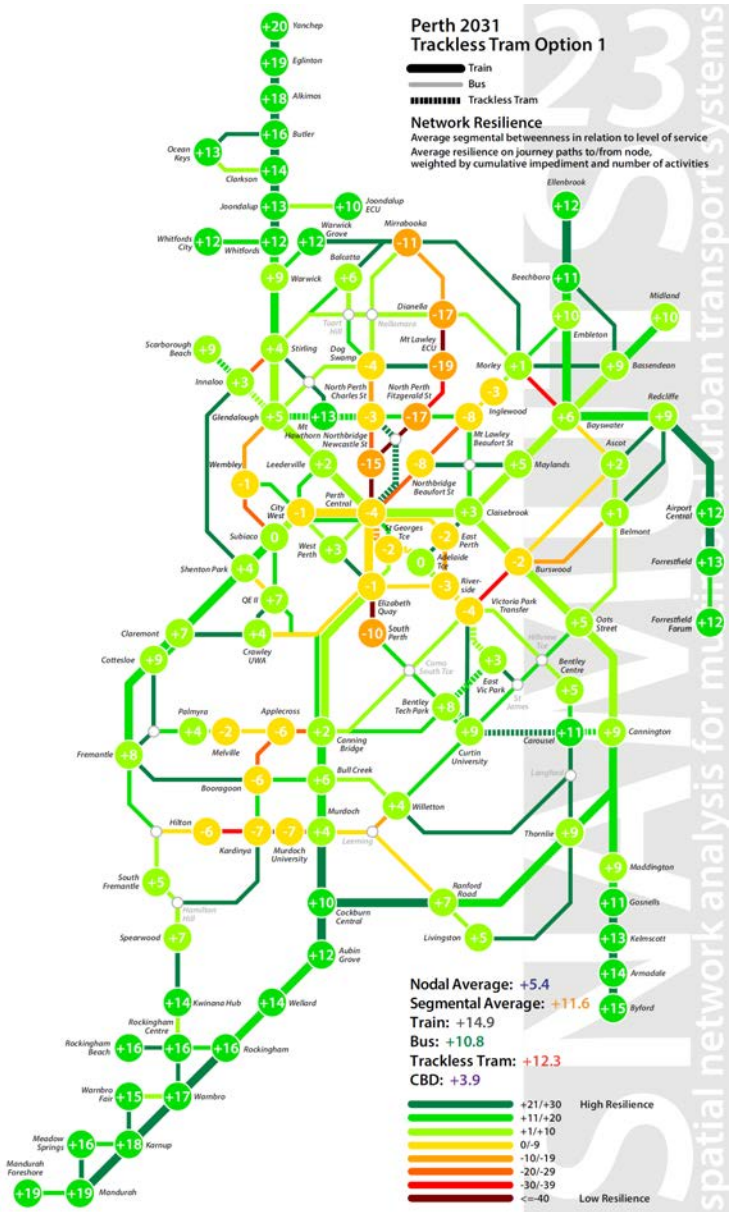
in particular the section between Curtin University and Carousel and the various route options in Perth's inner north between Glendalough and Perth Central station where the Trackless Tram loosely parallels the northern suburbs heavy rail line. Of these, it appears as though Option 2 (via Leederville) is the best positioned for network significance, and Option 1 (via Charles Street) the poorest. For each of these weaker sections, it is arguable that a land use intensification strategy will need to accompany the Trackless Tram investment in order to produce a viable return. Section 4 of this report will investigate this context in more detail.

On the second question, Options 1 and 2 reduce Perth's public transport network's dependence on movement to, from and through the (easily congested) CBD area slightly over the 2031 Trend (from 39.3% of all travel opportunities to 38.7% and 38.9% respectively), while Option 3 does not have a perceptible impact on this index. All three scenarios carve out a niche for the Trackless Tram in Perth's modal mix largely at the expense of the role of buses, which is to be expected as all three options replace some of Perth's busiest bus routes. However, Option 3 also slightly increases the role of rail over the 2031 Trend and thus has the greatest effect in relieving buses, the most vulnerable mode to overcrowding, from pressure to perform beyond its capacity. It also comes closest to equilibrium in terms of the roughly equivalent network significance of the three public transport corridors between the causeway and the heart of the CBD (Wellington St, St Georges/Adelaide Terrace and Riverside Drive), while Options 1 and 2 afford greater significance to the Wellington St bus route than the Terraces Trackless Tram one.

Network resilience

These discrepancies lead us to consider the SNAMUTS resilience performance of the three initial scenarios. Resilience acts as a proxy indicator for potential public transport congestion or for unmet, latent demand on public transport. It is calculated by drawing a ratio between the betweenness score and the public transport capacity provided on the journey path in question, on an open-ended downward scale from +30 (with green values from +30 to 0 indicating a good match between betweenness and capacity, yellow and orange values from 0 to -30 a cause for concern and red and maroon values below -30 a crisis point in resilience). The index helps identify local and global constraints for public transport to accommodate further growth in patronage from either urban





intensification/expansion or increasing mode share (or both), and assess how measures to boost the capacity and performance of the system can address these.

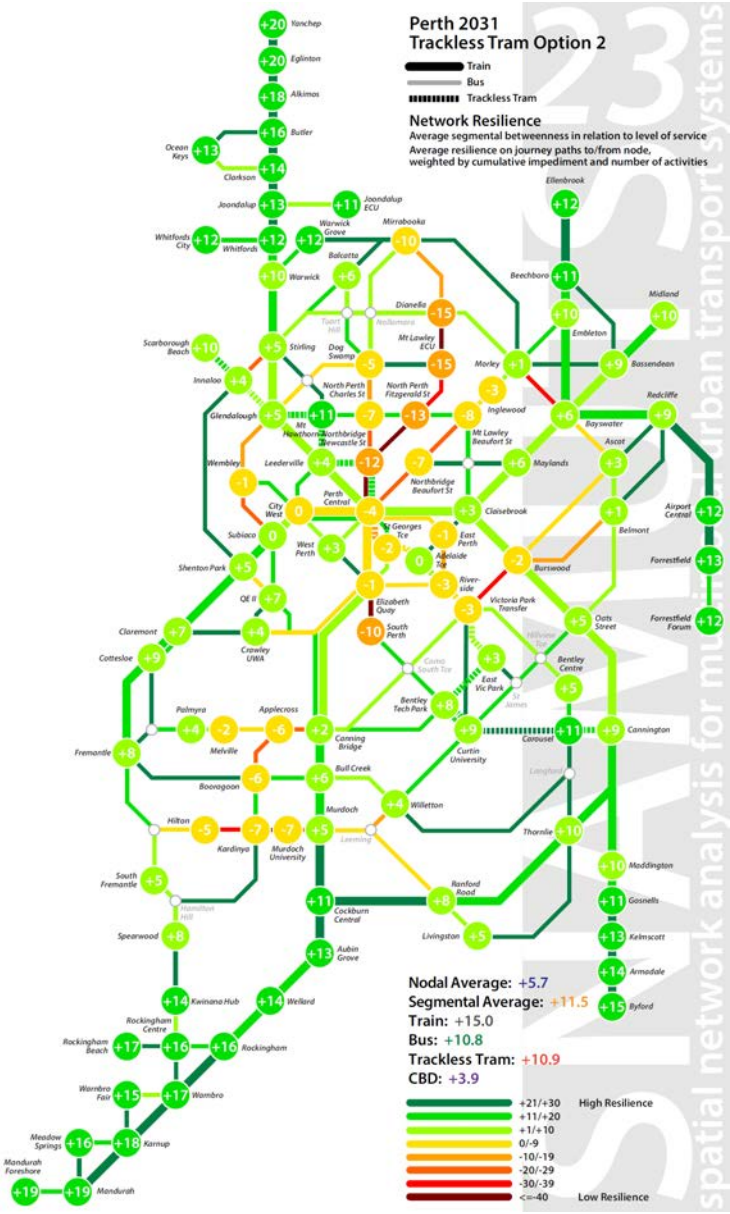
Figures 11-14: *SNAMUTS network resilience index for the 2031 Trend network and for Trackless Tram Options 1, 2 and 3*

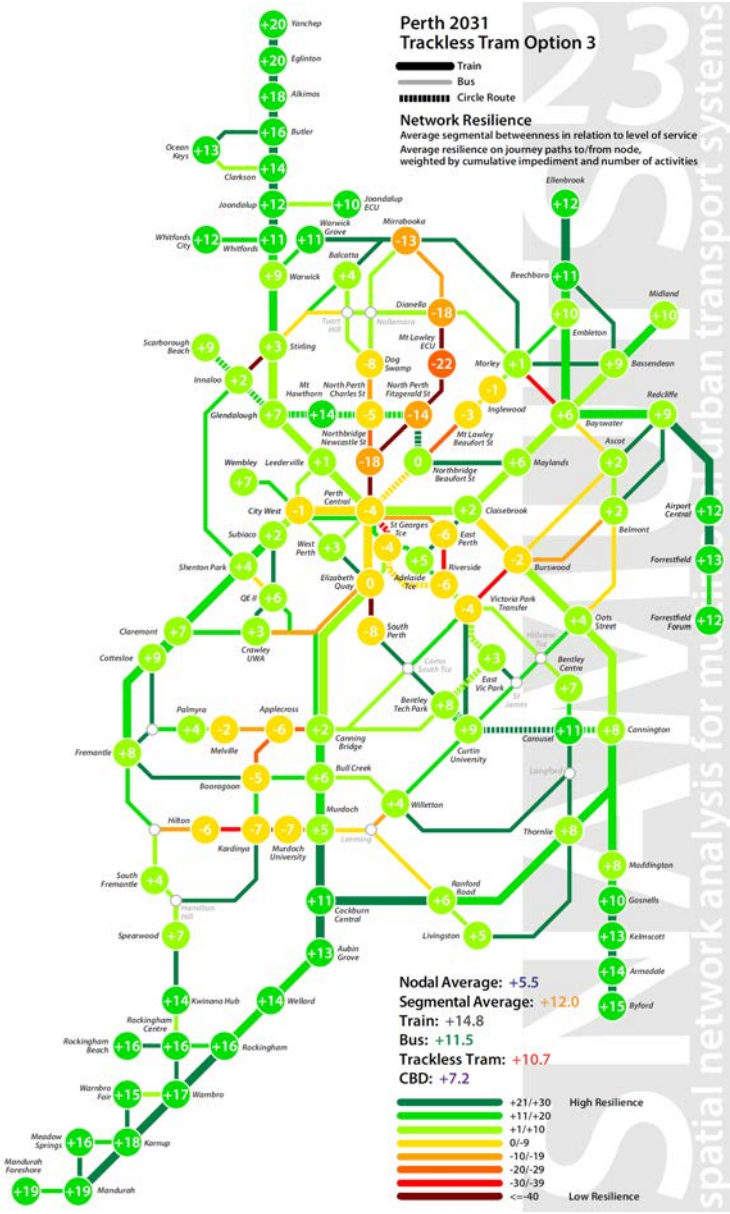
Figures 11-14 show that the Trackless Tram corridor proposed in Options 1-3 addresses several emerging resilience shortfalls on Perth's public transport system – the radial link to Curtin University and the routes in the North Perth-Mount Hawthorn area in particular can be expected to stretch the performance limits of a bus system by 2031 and are well placed for the upgrades offered by the Trackless Tram.

However, the worst discrepancy between network significance and

services/capacity offered can be found along the bus-based Fitzgerald Street-Alexander Drive corridor (one of the alignments of the abandoned MAX light rail proposal in the 2010s). The proposed Trackless Tram routes in the three initial scenarios have only marginal impact on this corridor – whether that is because they bypass some of North Perth's principal activity hubs (Option 1) or because the intersections between Trackless Trams and the radial bus routes in Perth's north are too close to the CBD to allow for significant travel time savings for passengers transferring there between bus and higher-capacity Trackless Trams (Option 3).

All three scenarios have a tangible impact on relieving the CBD area from potential public transport congestion, particularly along the south-eastern approach across the Causeway. However, the Wellington Street bus corridor





still displays resilience shortfalls in each option and suggests that the proposed CBD network configuration still has room for improvement in effectively reflecting the capacity and performance hierarchy of the Trackless Tram and bus components. We will explore this observation further in Section 5 of this report.

SECTION 3
Comparison of Options 4, 5 and X

This section expands the analysis of Trackless Tram scenarios by three further options that emerged during conversations with stakeholders and project team members in between the two workshops in October and December 2019.

We detected an interest on behalf of State Government to afford some focus to public transport upgrades along the north-eastern corridor anchored by the Morley regional centre, where the recent announcement of the Ellenbrook heavy rail branch aligns with the outer corridor section but does not service Morley centre or the inner corridor section between there and central Perth.

We were also interested in the potential of a more far-reaching removal of south-eastern radial bus routes from the Causeway and the Adelaide-St Georges Terrace corridors, their transformation into suburban feeder routes to link into heavy rail and Trackless Trams at Burswood and Victoria Park, and their redeployment to a greater number of additional or improved orbital bus routes to support the Trackless Tram in Perth's inner north and west.

Thus we devised the following three scenarios (Figures 15-17):

- **Option 4** describes a Trackless Tram route commencing at a new multimodal interchange at Burswood station, then leading via Victoria Park Transfer station, the Causeway, Adelaide and St Georges Terrace to William Street and Perth Central station. From there, the alignment continues through Northbridge to then follow Beaufort Street, Broun Avenue and Russell Street through Mount Lawley and Inglewood to Morley centre and further along Walter Road West to a new interchange on the proposed Ellenbrook rail line at Embleton.
- **Option 5** follows the same alignment as Option 4 between Burswood and Northbridge, but then continues along Fitzgerald Street and Alexander Drive through North Perth and the ECU Mount Lawley campus. From there, it skirts the northern edge of Mount Lawley golf course and follows Walter Road West to Morley centre, and further to the Embleton interchange as in Option 4.
- **Option X** is a variation of Option 2 (see previous section), optimised to allow for the conversion of more south-eastern bus routes into rail and Trackless Tram feeders, thus

removing them from the Causeway. It contains the Burswood to Victoria Park Transfer Trackless Tram branch that also features in Options 4 and 5. Unlike in Option 2, in this scenario Trackless Trams continue west beyond William Street along St Georges Terrace, then move to Hay Street at the freeway trench to access West Perth. From there, the alignment turns into Colin Street to then cross City West station, Loftus Street, the Mitchell Freeway and Leederville station on a dedicated viaduct providing interchanges to both the Fremantle and Joondalup-Yanchep rail lines. From Leederville, the route rejoins the Option 2 alignment north along Oxford Street.

Figures 15-17: *Overview of route variations for a Trackless Tram starter line in Perth (Options 4, 5 and X)*

SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION 4

2031 BASE NETWORK

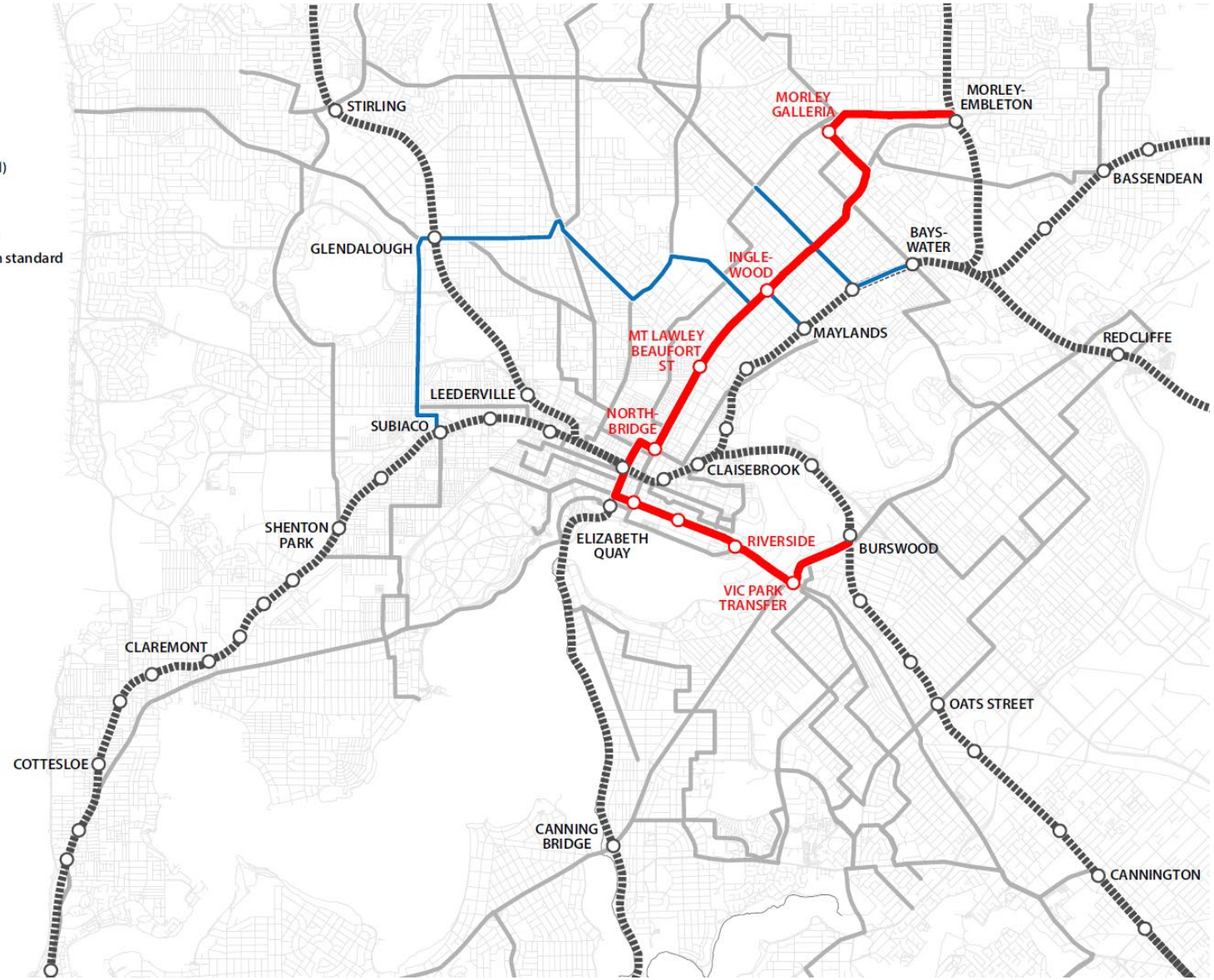
Heavy Rail with station

Bus (SNAMUTS minimum standard)

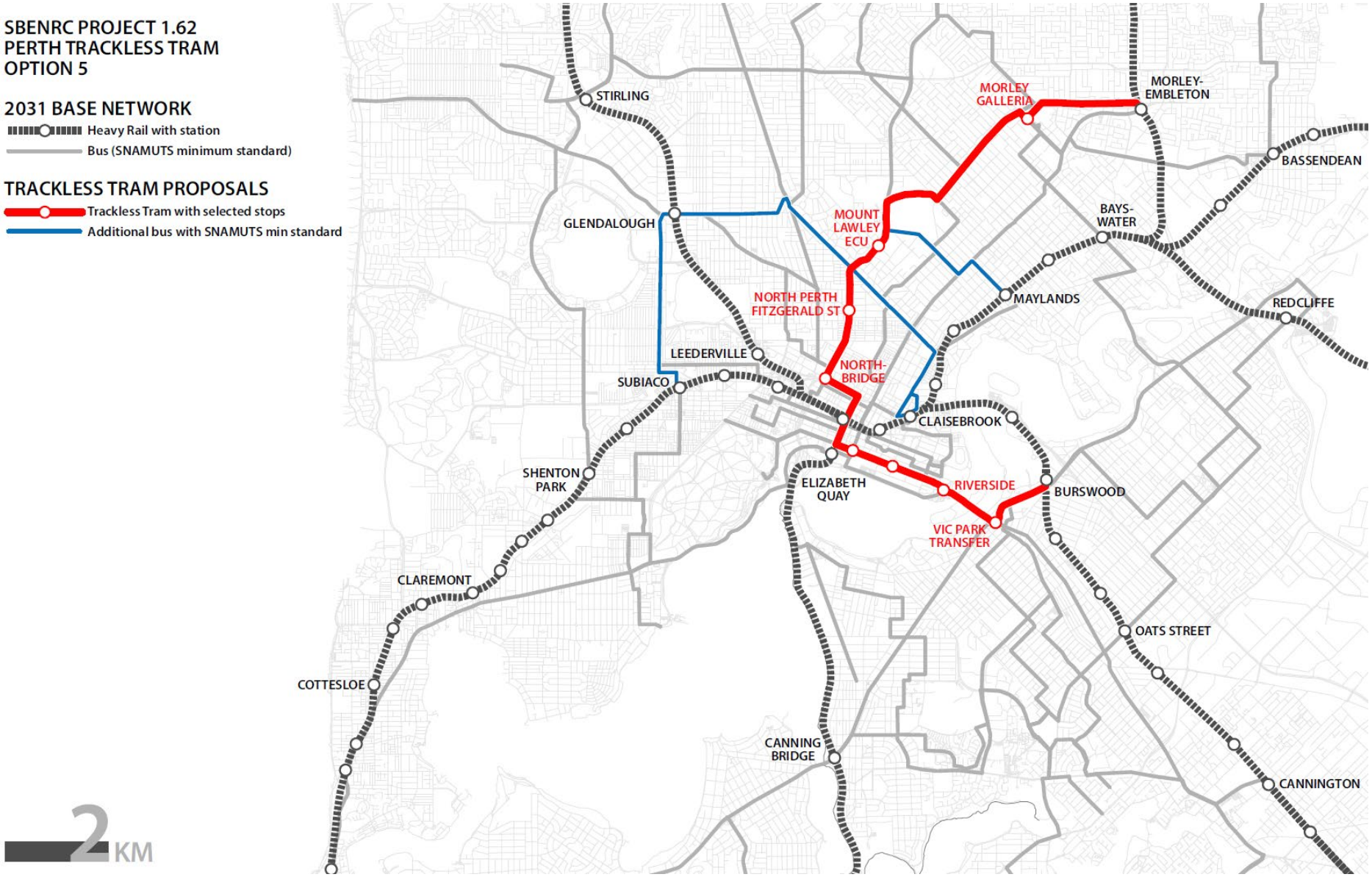
TRACKLESS TRAM PROPOSALS

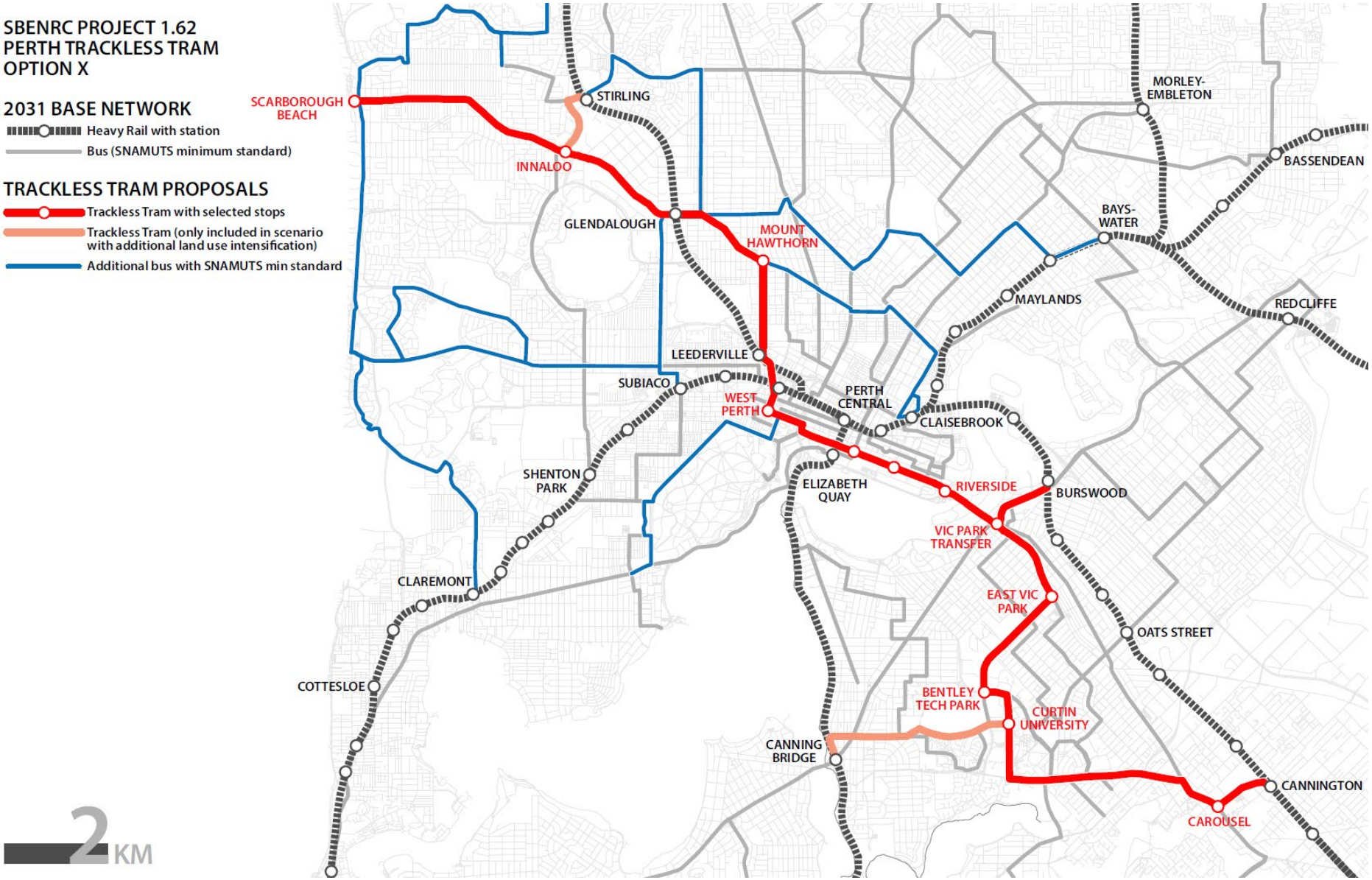
Trackless Tram with selected stops

Additional bus with SNAMUTS min standard



2 KM


SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION 5
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Additional bus with SNAMUTS min standard
STIRLING
MORLEY GALLERIA
MORLEY-EMBLETON
BASSENDEAN
GLENDALOUGH
MOUNT LAWLEY ECU
BAYS-WATER
NORTH PERTH FITZGERALD ST
MAYLANDS
REDCLIFFE
LEEDERVILLE
NORTH-BRIDGE
SUBIACO
CLAISEBROOK
SHENTON PARK
ELIZABETH QUAY
RIVERSIDE
BURSWOOD
VIC PARK TRANSFER
CLAREMONT
OATS STREET
COTTESLOE
CANNING BRIDGE
CANNINGTON
2 KM


SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION X
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Trackless Tram (only included in scenario with additional land use intensification)
Additional bus with SNAMUTS min standard
SCARBOROUGH BEACH
STIRLING
INNALOO
GLENDALOUGH
MOUNT HAWTHORN
MORLEY-EMBLETON
BASSENDEAN
BAYS-WATER
MAYLANDS
REDCLIFFE
LEEDERVILLE
SUBIACO
WEST PERTH
PERTH CENTRAL
CLAISEBROOK
SHENTON PARK
ELIZABETH QUAY
RIVERSIDE
BURSWOOD
VIC PARK TRANSFER
CLAREMONT
EAST VIC PARK
OATS STREET
COTTESLOE
BENTLEY TECH PARK
CURTIN UNIVERSITY
CANNING BRIDGE
CANNINGTON
CAROUSEL
2 KM

- **Both Option 4 and Option 5** describe shorter initial Trackless Tram routes than those depicted in Options 1, 2, 3 and X (15.8 and 16.5 km respectively as opposed to around 30 km). When interpreting SNAMUTS results, this factor should be taken into account – the network-wide improvements may inherently appear more modest than if a longer route was implemented.
- **Option 4 r**eplaces bus routes 950 and 67-68 between Perth Central station and Morley/Inglewood, while **Option 5** replaces bus routes 960 and 360-362 between Perth Central and ECU Mount Lawley. In both scenarios, bus routes 67-68 are improved in frequency. In Option 4, they are diverted at Inglewood to terminate at Maylands station. In Option 5, they are combined with route 60 and reach Elizabeth Quay via North and William Streets. Also in Option 5, Alexander Drive buses coming from the north are diverted via Walcott and Lord Streets to terminate at Claisebrook station. Both scenarios further contain the high-frequency orbital bus route between Subiaco and Bayswater/Maylands via Glendalough and ECU Mount Lawley already (partly) featured in Options 1 and 2 in order to increase multi-directional movement options in the catchments of the Trackless Tram corridors.
- **All three options** convert some south-eastern bus lines into rail and Trackless Tram feeders by through-routing them at Victoria Park Transfer and Burswood (eg. routes 910 and 36-40 are combined to form a continuous high-frequency line along Canning and Great Eastern Highways). Option X, however, goes further here than Options 4 and 5 by only leaving route 930 to continue into the CBD (via Wellington Street) via the Causeway, whereas Options 4 and 5 distribute the south-eastern bus routes remaining on the Causeway across Wellington Street and Riverside Drive (as in Options 1 and 2), freeing the Trackless Tram corridor along the Terraces from joint bus operations.
- **Option X** is the only scenario where the Trackless Tram does not directly access Perth's public transport 'superhub' at Central station. Instead, it is hoped that by offering three CBD fringe interchanges between Trackless Tram and rail, this route can relieve Perth Central station from congestion pressures by diverting travel paths to and from other CBD destinations – including Perth's highest concentration of employment at the western end of St Georges Terrace – away from it.

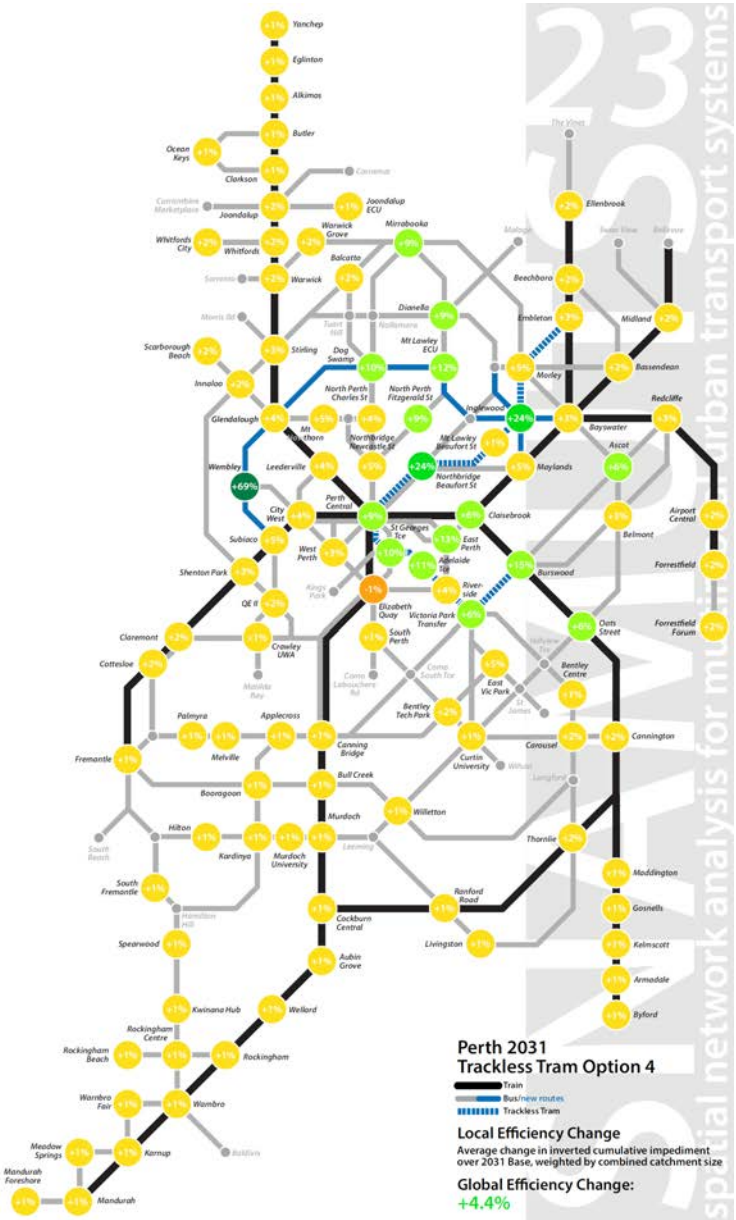
- **Option X** leads to the substantial savings in bus movements, thus allowing for the redeployment of buses to suburban orbitals (and some inner urban radials), as in Options 1 and 2 but including more routes particularly in the Stirling-Scarborough area.
- **Weekday daytime service frequencies** on the Trackless Tram in Option 4 are every 7 1/2 minutes along the entire route and 3 3/4 minutes between Burswood and Northbridge. In Option 5, Trackless Trams operate every 8 minutes along the entire route and every 4 minutes between Burswood and ECU Mount Lawley. In Option X, daytime frequencies are 6 2/3 minutes each between Scarborough Beach and Cannington and between Leederville and Burswood, leading to 3 1/3 minute intervals along the common section through the CBD between Leederville and Victoria Park Transfer. These frequencies have been determined in an iterative process intended to optimise SNAMUTS resilience performance (see below).
- **End-to-end running times** are estimated at 42 minutes in Option 4 (average speed 22.6 km/h), 43 minutes in Option 5 (average speed 23.0 km/h) and 70 minutes in Option X (average speed 24.6 km/h including the Burswood branch).

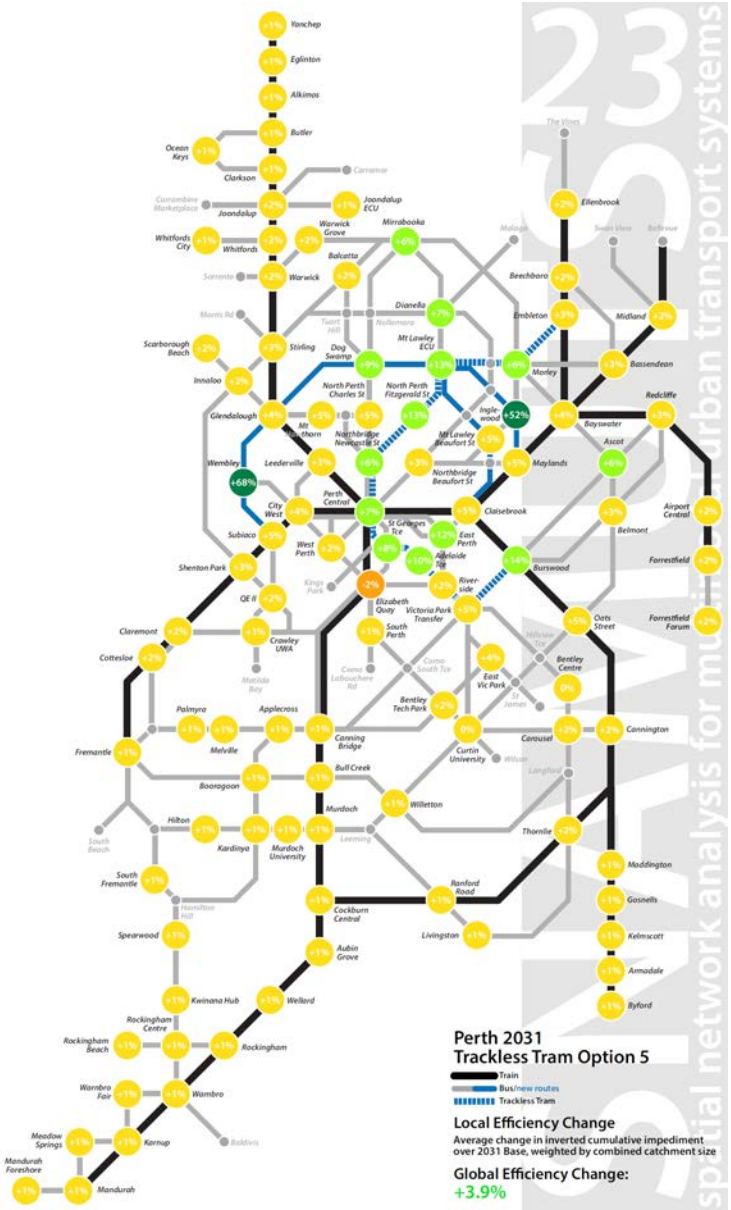
In the SNAMUTS analysis below, we are interested in finding out how Options 4 and 5 hold up comparatively with Options 1, 2 and 3 assessed in the previous section and how they compare to each other as alternative alignments along the same broader corridor. We are also interested in the magnitude of additional improvement achieved in the route optimisation and further bus redeployment in Option X, as well as potential shortcomings associated with these measures.

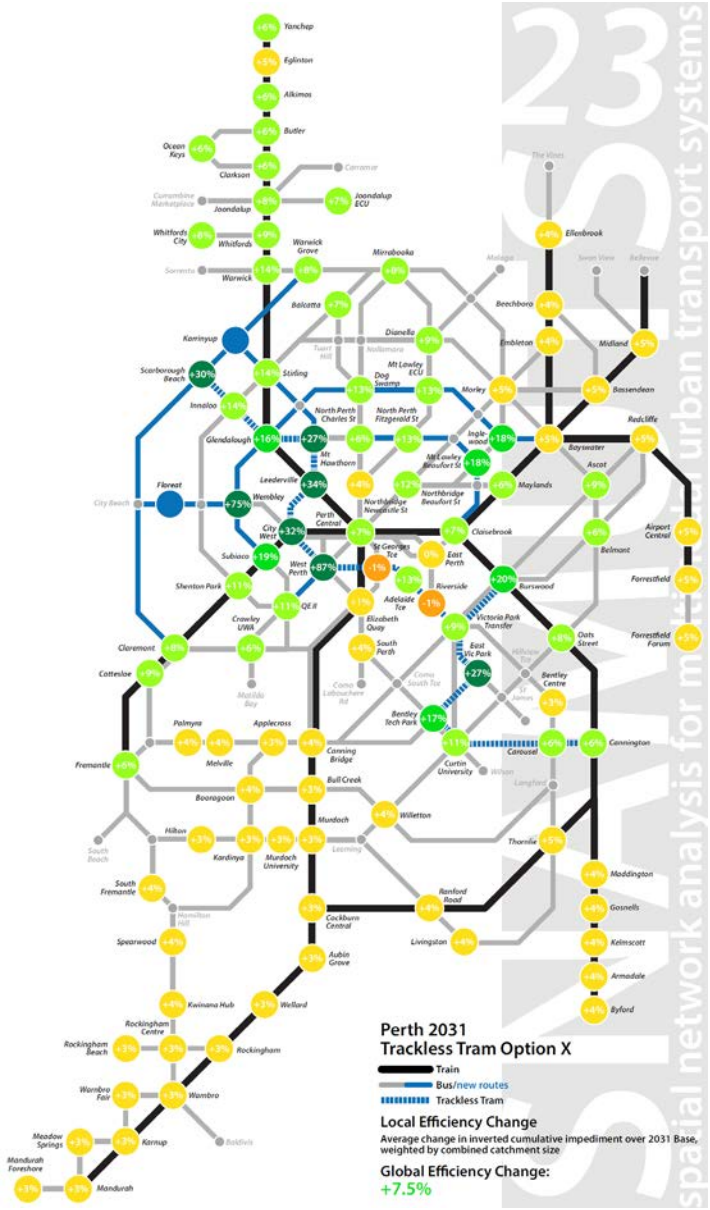
Efficiency Change

Figures 18-20 show the local and global efficiency change diagrams for Trackless Tram Options 4, 5 and X (see section 2 of this report for a description of this index).

Comparing the two alternative Trackless Tram alignments along the Morley corridor, the global efficiency improvement in Option 4 (Beaufort Street) is slightly greater than that in Option 5 (Fitzgerald Street-Alexander Drive). This is mostly manifest at the CBD nodes, but less so along the suburban corridor where it appears as though the configuration of







additional connecting bus routes has a greater influence on this index than the Trackless Tram alignment itself. It is also conspicuous that the insertion of the Trackless Tram has only a minor impact at the outer end of the proposed route (Morley and Embleton) in both scenarios.

Figures 18-20: *SNAMUTS efficiency change network diagrams for Trackless Tram Options 4, 5 and X over the 2031 Trend (see Figures 15-17)*

The global efficiency improvement of 4.4% in Option 4 and 3.9% in Option 5 compares favourably with the scenarios assessed in the previous section, were Options 1 and 2 delivered a similar increment despite containing Trackless Tram routes of nearly twice the length.

Option X increases the global efficiency of Perth's public transport network by a significantly greater margin

than any of the scenarios previously assessed. The interplay of the Trackless Tram route and the improved multidirectional bus network along the north-western branch spreads notable accessibility benefits across its wider catchment, as far even as more outlying nodes along the Joondalup-Yanchep and Fremantle rail lines. The benefits along the south-eastern branch are more moderate and more localised (but still tangible). In contrast, efficiency stagnates at some CBD locations, but this is not necessarily a problem since it is capacity and resilience (measured by other SNAMUTS indicators) that poses a greater challenge in this area than the (already quite efficient) connection of land use concentrations measured by this index.

A glance at the metropolitan averages on other SNAMUTS indicators (Table 2) confirms the relative equivalence of results between Options 4 and 5, and the significant outperformance of Options 1 and 2 (assessed in the previous section) by optimised Option X. Two items stand out from this table: Option 5 breaks out positively on average network resilience, suggesting it may hold some insight about how better to address Perth's most pressing problems of potential public transport congestion and/or failure to pick up potential patronage. Option X scores particularly highly on average nodal betweenness, suggesting it may unleash a capability to service a significant proportion of new trip relations that the 2031 Trend configuration and the other scenarios do not achieve to the same extent.

Table 2: *Overview of average SNAMUTS indicator results for Trackless Tram Options 1, 2, 3, 4, 5 and X, and the 2031 Trend network (without Trackless Trams)*

2031 SNAMUTS *23R*	Trend	Option 1	Option 2	Option 3	Option 4	Option 5	Option X
Average Closeness Centrality Metropolitan Perth	47.8	46.9	46.9	47.5	47.1	47.2	46.8
Average Degree Centrality Metropolitan Perth	1.01	0.98	0.98	0.99	0.99	0.99	0.98
Average 30-min Contour Catchment Metropolitan Perth	14.6%	15.6%	15.7%	15.0%	15.4%	15.4%	15.9%

2031 SNAMUTS *23R*	Trend	Option 1	Option 2	Option 3	Option 4	Option 5	Option X
Average Nodal Betweenness Metropolitan Perth	50.8	51.5	51.7	50.9	50.6	50.2	53.0
Average Nodal Resilience Metropolitan Perth	+3.4	+5.4	+5.7	+5.5	+5.3	+6.4	+5.3
Average Nodal Connectivity Metropolitan Perth	31	34	35	33	34	34	35
Global Efficiency Change Metropolitan Perth		+4.4%	+4.6%	+1.9%	+4.4%	+3.9%	+7.5%
Average SNAMUTS Composite Score Metropolitan Perth	19.3	20.1	20.2	19.7	19.9	20.0	20.5

Betweenness centrality

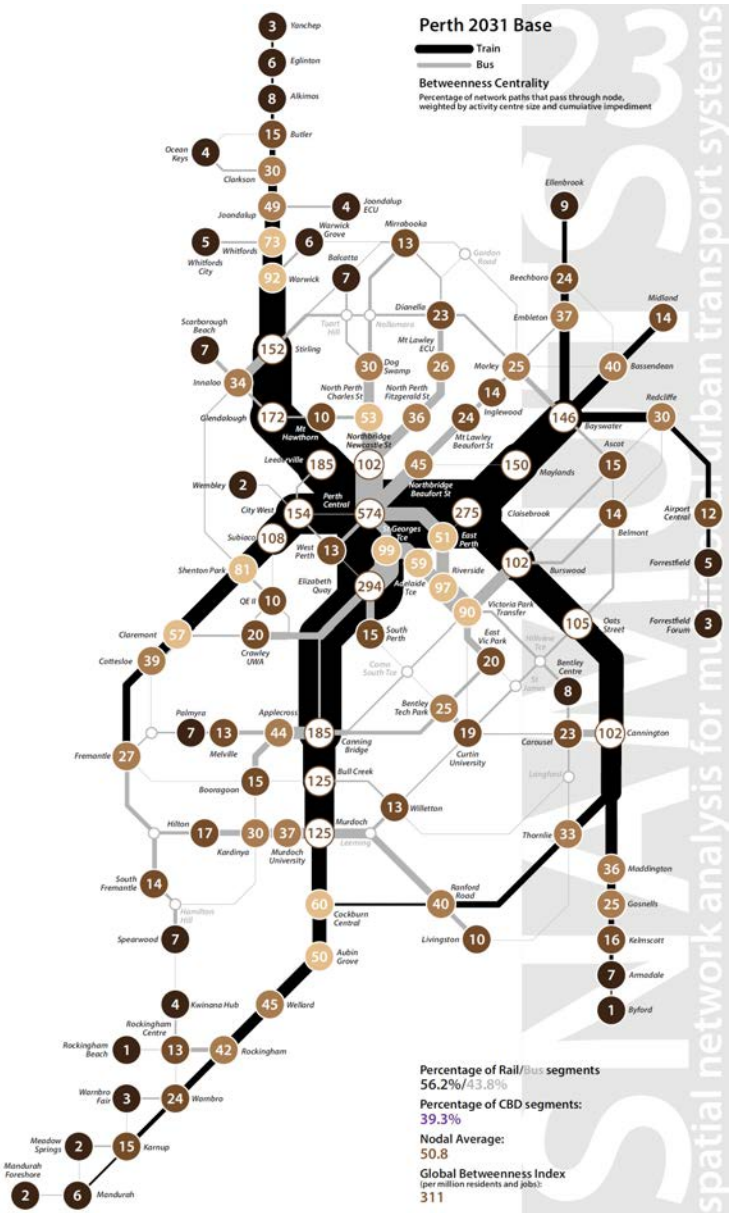
The betweenness analysis in Figures 21-24 (see Section 2 for a description of this index) illustrates the capability of Option X to open up a new and very prominent movement corridor in the western CBD and CBD fringe. The nodal betweenness figures for the rail-Trackless Tram transfer points of Leederville and City West increase markedly over the 2031 Trend. West Perth, almost in an 'end-of-the-line' position on the 2031 Trend network (and remaining so in Options 1-5) achieves the level of importance for channelling movement opportunities that is commensurate with its geographical location as well as its character as a medium to high density residential and employment hub.

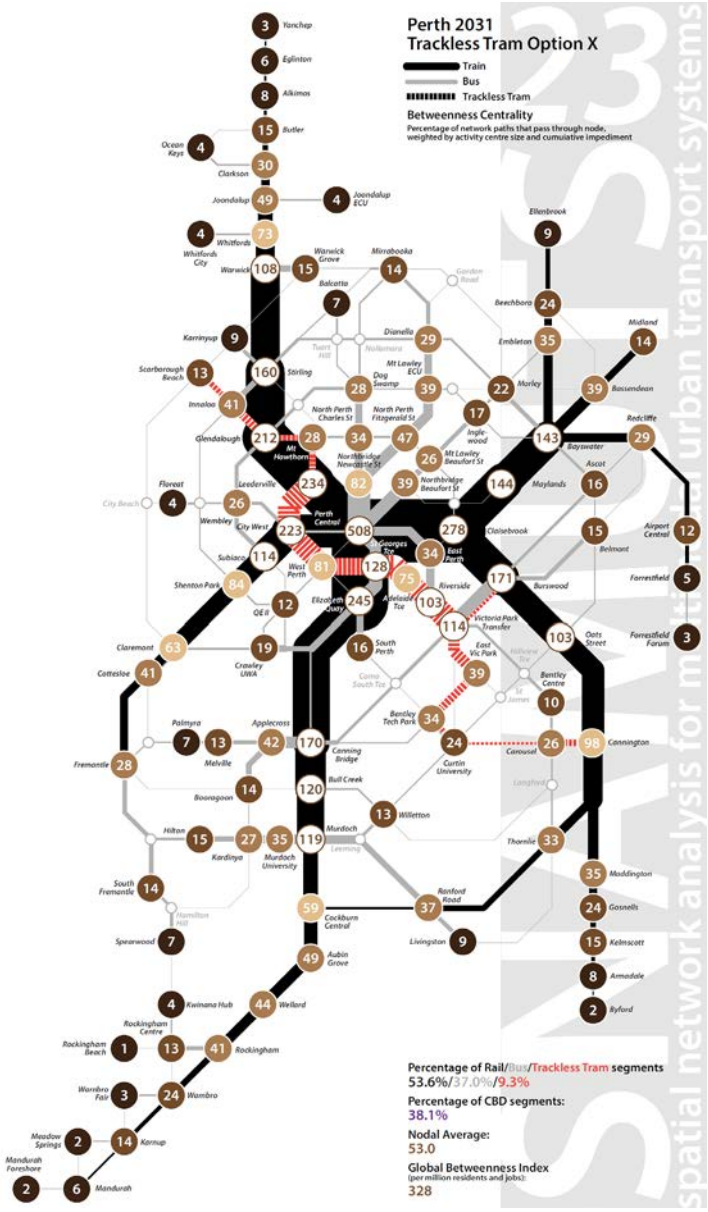
Conversely, there is a tangible reduction of nodal betweenness performance at Perth Central station, suggesting the Trackless Tram alignment in this scenario succeeds in distributing movement opportunities away from Perth's 'super-hub' and thus providing relief from potential congestion there. Clearly, Option X makes it attractive for radial rail passengers to transfer to the Trackless Tram

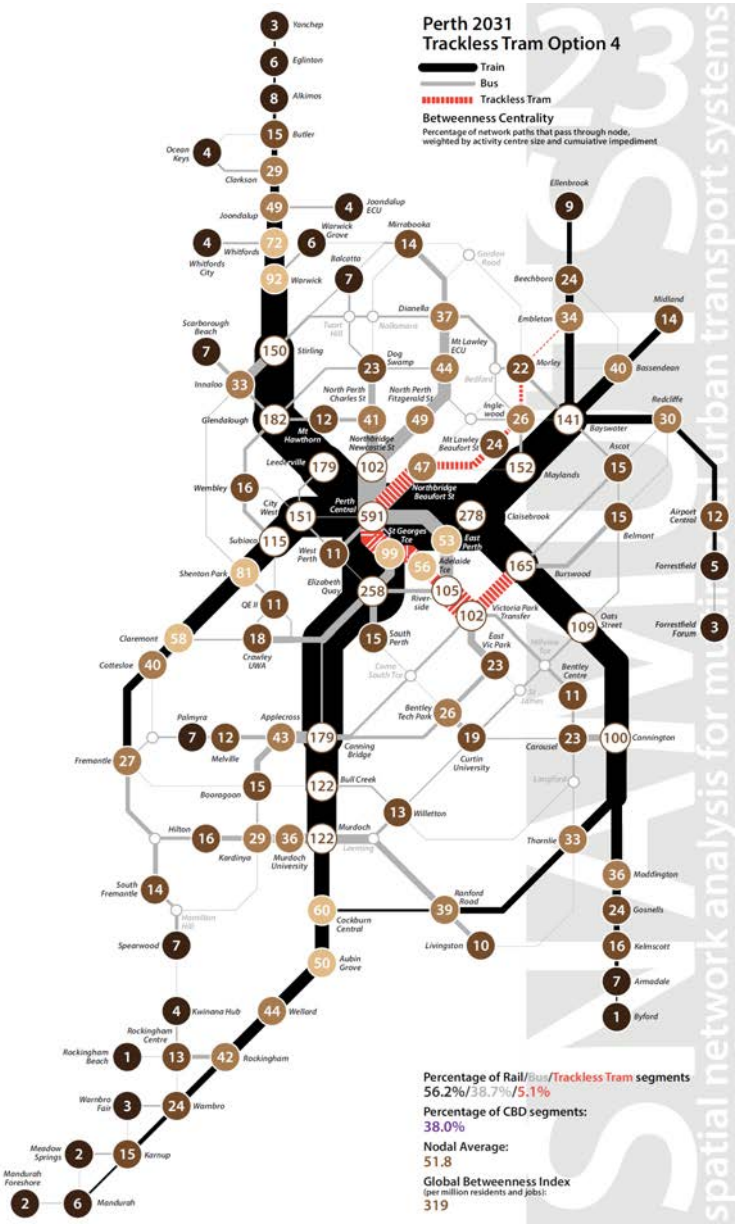
before reaching Perth Central station and reach destinations particularly in the western CBD faster than is currently the case.

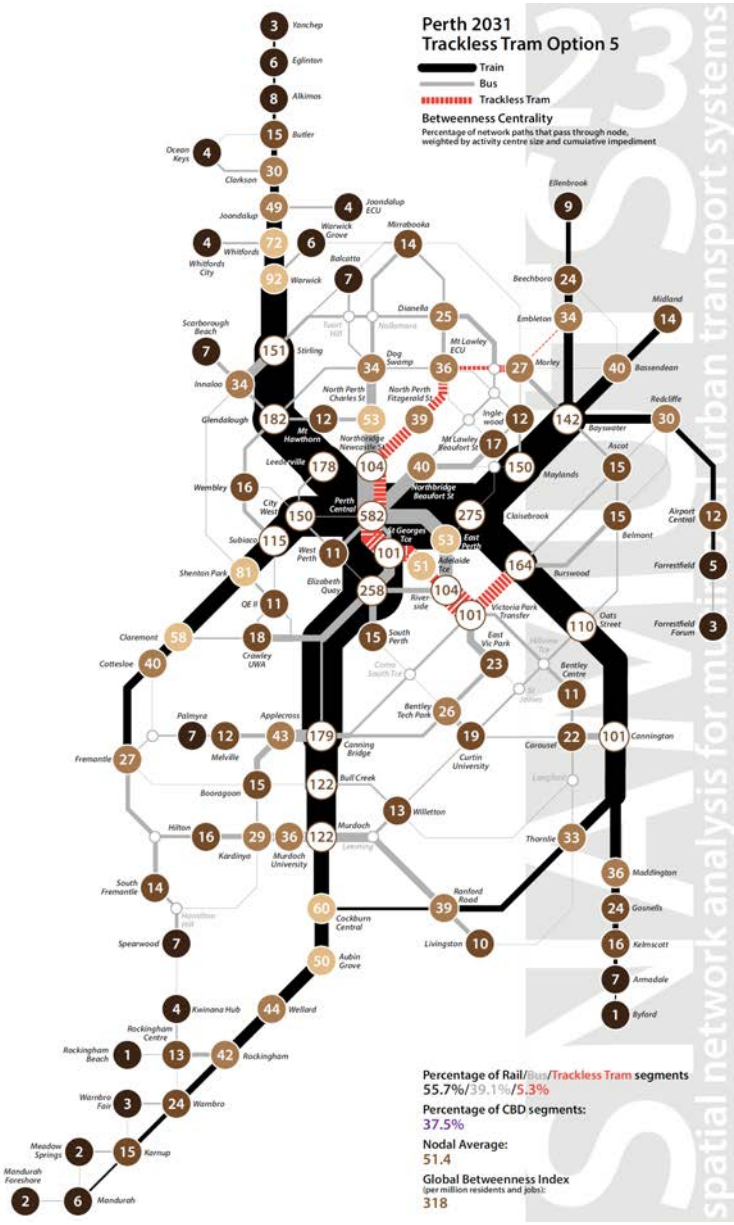
Comparing the betweenness results for Options 4 and 5, it becomes apparent that the two scenarios do not differ much in how they channel movement opportunities in the CBD area. However, in Perth's inner north the results suggest that Option 5 enables a better balance between the three main radial on-street public transport corridors of Charles Street, Fitzgerald Street and Beaufort Street than Option 4, by distributing travel opportunities more evenly among them and thus avoiding excessive spikes that may be associated with congestion or underperformance.

Figures 21-24: *SNAMUTS betweenness centrality index for the 2031 Trend network and for Trackless Tram Options X, 4 and 5*



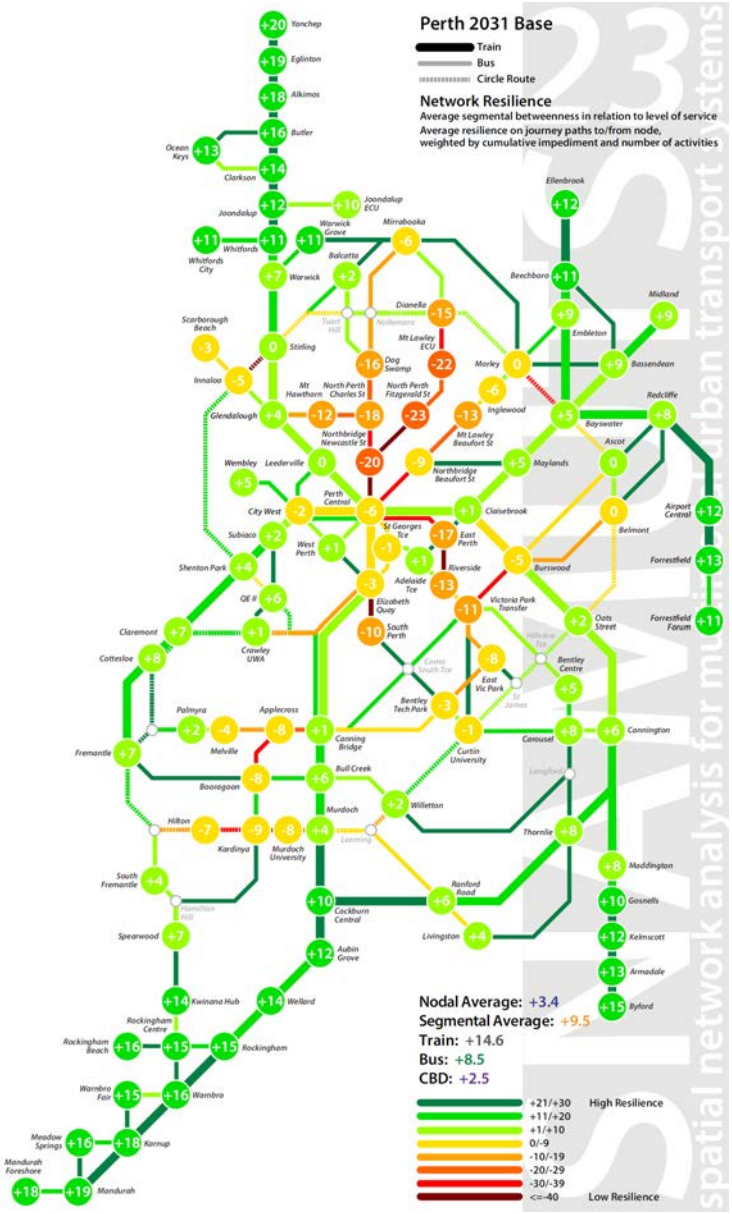


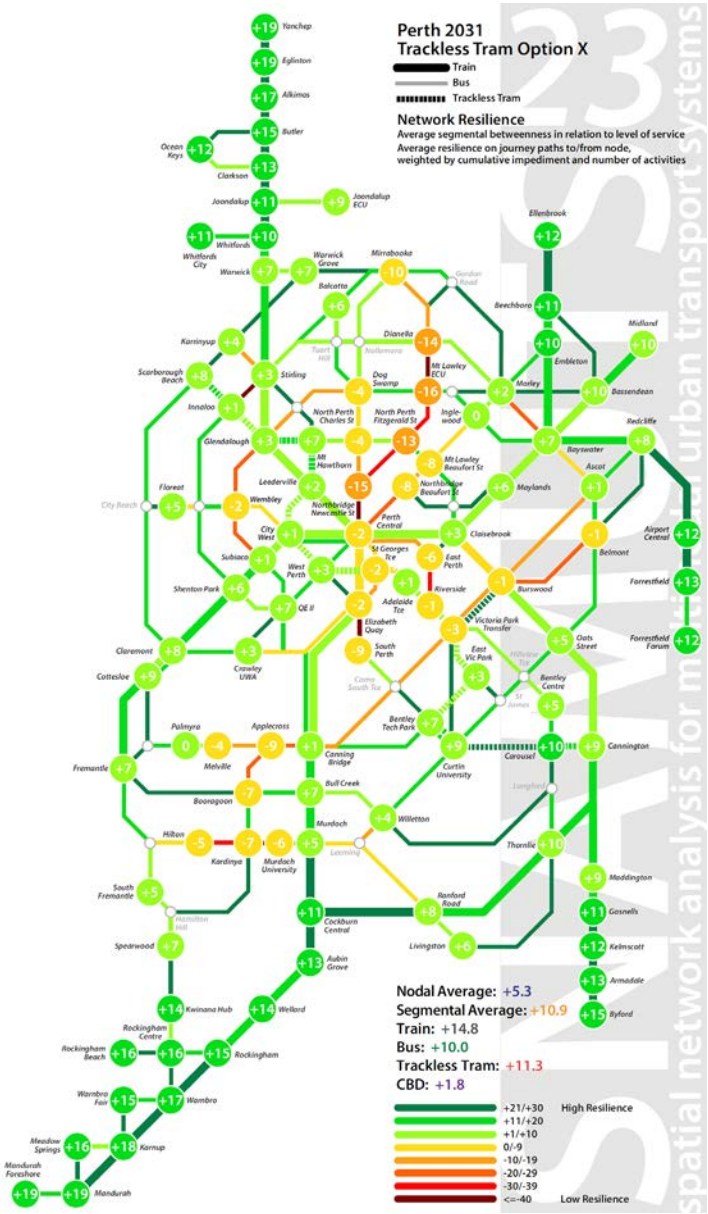

Perth 2031
Trackless Tram Option 4
Train
Bus
Trackless Tram
Betweenness Centrality
Percentage of network paths that pass through node, weighted by activity centre size and cumulative impediment
Percentage of Rail/Bus/Trackless Tram segments
56.2%/38.7%/5.1%
Percentage of CBD segments:
38.0%
Nodal Average:
51.8
Global Betweenness Index
(per million residents and jobs):
319
spatial network analysis for multi-urban transport systems

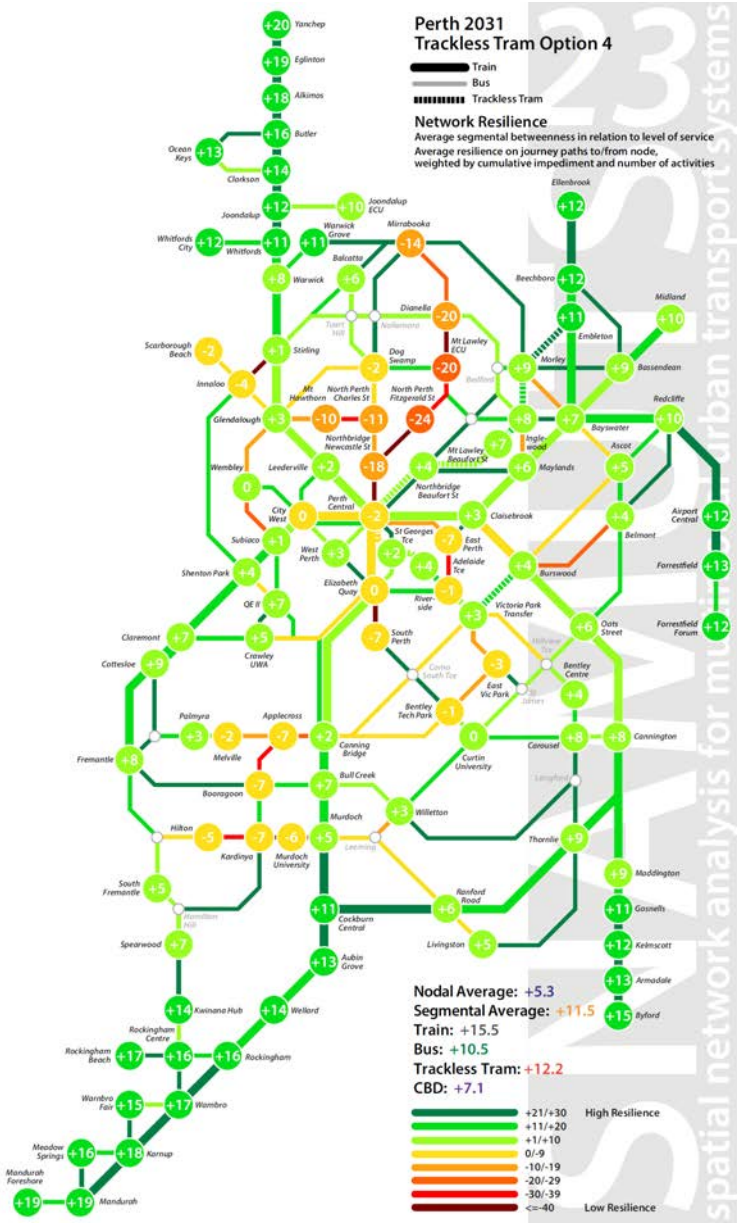

Perth 2031
Trackless Tram Option 5
Train
Bus
Trackless Tram
Betweenness Centrality
Percentage of network paths that pass through node, weighted by activity centre size and cumulative impediment
Percentage of Rail/Bus/Trackless Tram segments
55.7%/39.1%/5.3%
Percentage of CBD segments:
37.5%
Nodal Average:
51.4
Global Betweenness Index
(per million residents and jobs):
318
spatial network analysis for multi-urban transport systems

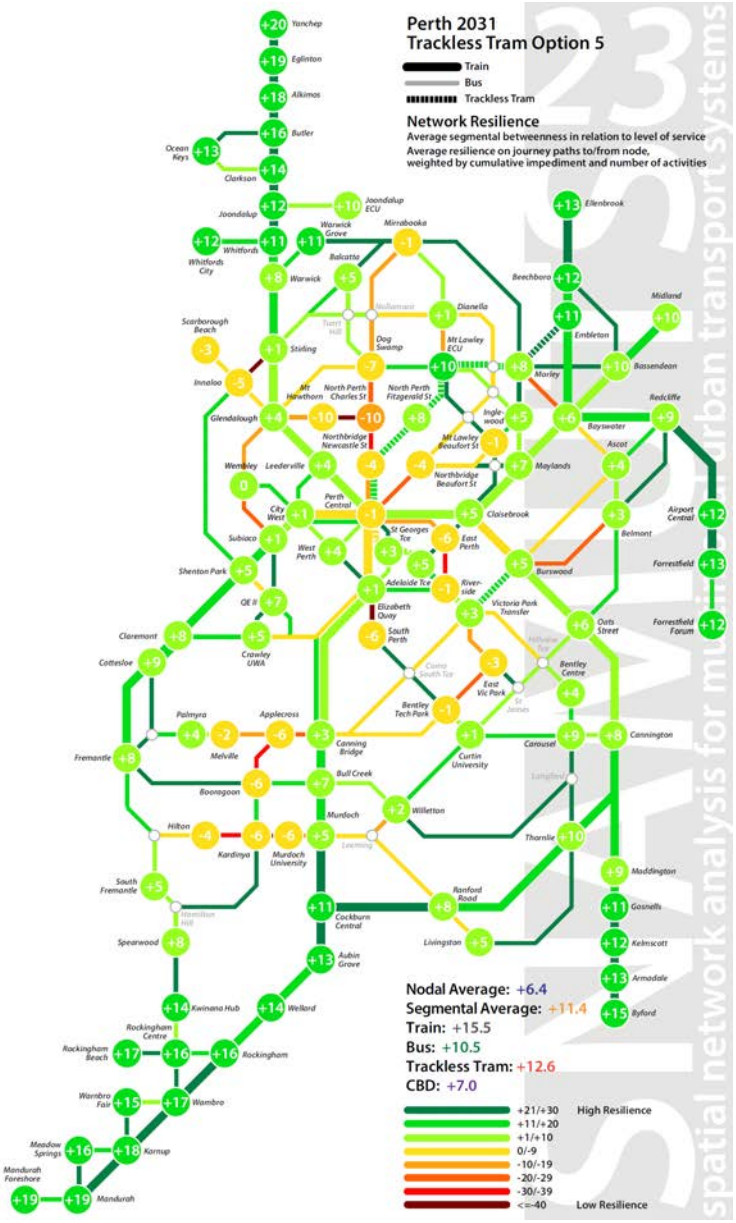
Network resilience

This relative equilibrium between transport corridors in Perth's inner north translates into a superior resilience performance of Option 5 over Option 4, as shown in Figures 25-28 (see Section 2 for a description of this index). Fitzgerald Street and Alexander Drive, home to Perth's poorest-resilience bus routes in the 2031 Trend network, experience tremendous relief in this scenario. This is due to two factors: The conversion of the inner section (south of ECU Mount Lawley) from bus to Trackless Tram increases the capacity and performance of the corridor. Additionally, radial travel opportunities from the Dianella-Mirrabooka area, which along Alexander Drive now face a bus to Trackless Tram transfer at ECU Mount Lawley, are partially redistributed to the Charles Street corridor further west (route 970) and the new









combined bus route 60/67 further east.

Average resilience levels across metropolitan Perth in Option X improve by a similar margin as in Options 1 to 4. However, in the CBD area, and unlike in any of the previous scenarios, they drop. This might suggest that the near-elimination of bus routes crossing the Causeway to and from Perth inner south-east, forming a central tenet of this scenario, has either gone too far or is not adequately compensated for by the single Trackless Tram route along the Terraces that does not access Perth Central station. We will revisit this shortfall in Section 5 of this report, where two additional scenarios have been constructed to address it.

Figures 25-28: *SNAMUTS network resilience index for the 2031 Trend network and for Trackless Tram Options X, 4 and 5*

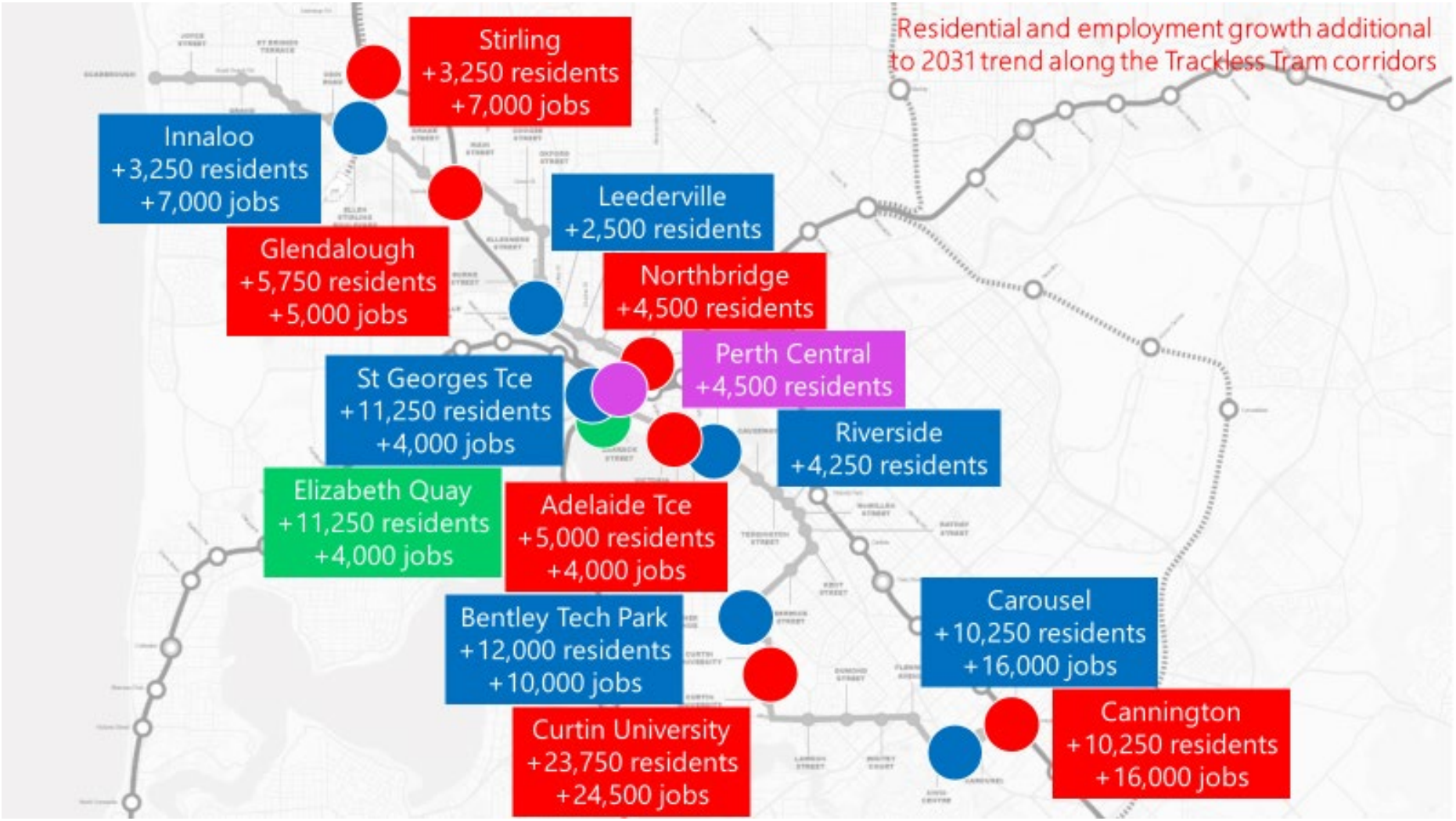
SECTION 4
Intensifying land use around the Trackless Tram

The scenarios described in the previous sections have been developed to assess the accessibility impact of different network configurations in Perth in 2031, with and without several variations for an initial Trackless Tram operation in the city. Thus far however, these scenarios have been built on an assumption of unmodified trends in population and employment growth during that period, in order to isolate the effect of transport network changes in the scenario comparison. Since SNAMUTS is a tool to assess the integration of land use *and* transport, it can be expected that once the land use component is also subject to modification, the results on most indicators will be further influenced.

The Entrepreneurial Rail Model[3] utilised to form a significant rationale and identify funding sources for the introduction of a medium-capacity mode to Perth expressly anticipates land use intensification over and beyond the 2031 trend to occur in the catchments of the new Trackless Tram routes. In conversations with the local governments forming part of the project consortium, potential urban intensification and redevelopment areas were identified and a target size determined for future residents and jobs. These target sizes were assessed against the projections already included in the 2031 STEM population and employment estimates, and an increment of additional growth over and beyond these trends calculated for each activity node. Figure 29 illustrates these figures as used in Options 1, 2, 3 and X. In Options 4 and 5, only those nodes actually accessed by the (shorter) Trackless Tram routes (Northbridge, Perth Central, Elizabeth Quay, St Georges Terrace, Adelaide Terrace and Riverside) carry additional growth assumptions. In addition, some intensification potential has also been identified and included in the Mount Lawley-Inglewood area and incorporated only in the land use assumptions for Options 4 and 5.

[3] Newman P, Mouritz M, Davis-Slate S, Jones E, Hargroves K, Sharma R, Adams D (2018) *Delivering Integrated Transit, Land Development and Finance. A Guide and Manual with Application to Trackless Trams.* Sustainable Built Environment National Research Centre (SBENRC), Australia

Figure 29: *Assumptions for residential and employment growth in the catchments of activity nodes along Trackless Tram routes over and beyond 2031 projections (Options 1, 2, 3 and X)*



Apart from significant further urban intensification in the CBD area, these assumptions identify three major suburban employment and residential growth hubs in Stirling-Innaloo, Curtin University-Bentley Tech Park and Carousel-Cannington. They also assume an above-trend rate of more fine-grained, incremental, mostly residential intensification around inner suburban activity corridors such as Scarborough Beach Road and Beaufort Street once these have been supplied with Trackless Tram infrastructure and services.

For the sake of easy comparability, it is assumed that the overall metropolitan growth projection for 2031 remains constant in all scenarios, both with and without land use components. This implies that the additional growth around the Trackless Tram corridors is anticipated to occur at the expense of, or by delaying beyond 2031, trend growth in areas away from easy public transport access, such as in greenfield areas at the urban fringe.

It should be noted that the overall assumptions for Trackless Tram-oriented land use intensification may appear ambitious for an 11-year time horizon – in Options 1, 2, 3 and X, they amount to more than 5% of all metropolitan residents and jobs in 2031 having concentrated in these areas in addition to existing trends (see Table 3). In reality, the rate of growth may be lower or take longer than 2031 to materialise. However, this does not weaken the SNAMUTS analysis in the sense that the figures used here can be understood as an 'intensification maximum', allowing us to perform a 'stress test' for the land use-transport system on the basis of these assumptions. This will particularly affect the betweenness, resilience and mode capitalisation indexes (see below).

Taking in insights from the previous round of analysis (sections 2 and 3 of this report), some assumptions about network configuration and service levels for the Trackless Tram scenarios were modified in this step. In particular, it was identified that the concentration of travel opportunities drops off towards either end of the starter line in Scenarios 1, 2, 3 and X, offering the opportunity to add additional Trackless Tram branches from Innaloo to Stirling and Curtin University to Canning Bridge respectively, in order to improve movement opportunities in these major growth centres. Effectively, this configuration leads to an operational pattern of two separate Trackless Tram lines, where one line links Cannington and Scarborough Beach and the other Canning Bridge and Stirling, with a common trunk section between Curtin University and Innaloo.

In Options 1 and 2, both these lines are assumed to operate at daytime frequencies of 8 minutes, adding up to 4-minute intervals on the common section. In Option 3, each line operates every 10 minutes, with 5-minute intervals on the common section. In Options 4 and 5, Trackless Tram frequencies have not been modified from those in the land use-neutral scenarios in the previous section. In Option X, a 4-line network is assumed to operate at 10-minute daytime frequencies each: Cannington-Scarborough Beach, Canning Bridge-Stirling, Burswood-Leederville and Cannington-Canning Bridge via Curtin University, resulting in 5-minute intervals anywhere between Innaloo and both southern termini, and average 3 1/3-minute intervals between Victoria Park Transfer and Leederville.

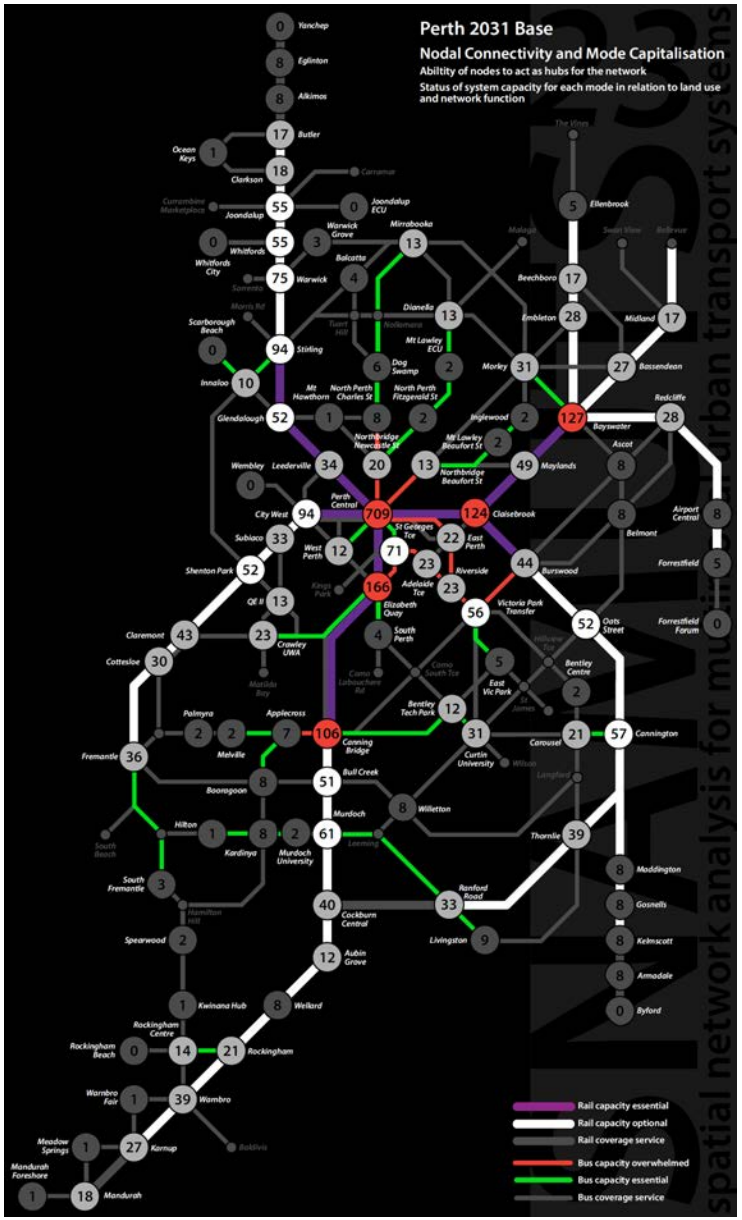
To compensate for the increased frequency on the Trackless Tram routes while keeping metropolitan-wide operational input constant, the orbital bus route between Claisebrook and Stirling via Mount Lawley, North Perth and Mount Hawthorn has been dropped from Options 1 and 2 in this section. Option X retains all of its additional bus routes, though some are assumed to operate at lower frequencies than in the land use-neutral scenario from the previous section.

Table 3: *Overview of average SNAMUTS indicator results for Trackless Tram Options 1, 2, 3, 4, 5 and X including additional land use assumptions, and the 2031 Trend network (without Trackless Trams)*

2031 SNAMUTS *23R*	Trend	Option 1 + LU	Option 2 + LU	Option 3 + LU	Option 4 + LU	Option 5 + LU	Option X + LU
Average Closeness Centrality Metropolitan Perth	47.8	46.7	46.7	47.3	47.1	47.2	46.6
Average Degree Centrality Metropolitan Perth	1.01	0.98	0.97	0.99	0.99	0.99	0.98
Average 30-min Contour Catchment Metropolitan Perth	14.6%	17.7%	17.8%	17.3%	16.2%	16.3%	18.2%
Network Coverage (percentage of metropolitan residents and jobs)	52.0%	57.9%	57.9%	57.7%	54.0%	53.9%	59.7%

2031 SNAMUTS *23R*	Trend	Option 1 + LU	Option 2 + LU	Option 3 + LU	Option 4 + LU	Option 5 + LU	Option X + LU
Average Nodal Betweenness Metropolitan Perth	50.8	56.0	56.4	55.4	51.7	51.3	57.7
Average Nodal Resilience Metropolitan Perth	+3.4	+4.6	+4.7	+4.5	+4.8	+5.9	+4.0
Average Nodal Resilience CBD	+2.5	+3.5	+3.4	+5.6	+5.7	+5.2	-0.5
Average Nodal Connectivity Metropolitan Perth	31	37	38	36	34	34	38
Global Efficiency Change Metropolitan Perth		+25.2%	+25.6%	+22.1%	+14.0%	+13.0%	+27.0%
Average SNAMUTS Composite Score Metropolitan Perth	19.3	21.3	21.3	21.0	20.3	20.4	21.7

Table 3 shows that the addition of a land use component to the analysis greatly increases the efficiency benefits of the network options – put simply, more residents and jobs are linked by better public transport. The gap between Options 1/2 and Option X on the global efficiency index narrows. Options 4 and 5, where less overall land use intensification is assumed to occur along shorter routes, fall more conspicuously behind the other scenarios in this assessment. Option 5 retains its first-ranked position in terms of average resilience, while Option X continues to be ranked poorest on this index and drops into negative resilience figures in the CBD area. While there is merit in creating a continuous route along the Terraces linking the western and eastern ends of the CBD with a fast, frequent and legible service, the absence of a Trackless Tram connection into Perth's 'super-hub' at Central station in this scenario places excessive pressure on the remaining CBD bus routes that do provide this link. Scenarios Y and Z in the final section of this report are designed to alleviate this problem.



Mode capitalisation assessment

This index has been developed to inform us whether a particular route segment attracts a level of travel opportunities that is commensurate with the mode that is offered there, in terms of its capacity and performance characteristics. Critically, mode capitalisation seeks to identify the threshold at which a bus route may become overwhelmed with the transport task assigned to it, and the introduction of a higher-capacity mode becomes imperative if the public transport system is to remain operationally effective and an attractive choice for passengers. As land use intensification increases and as more people choose to make public transport the default option for their movement needs, this threshold can be expected to drop. These factors are considered in the calibration of this index.

Mode capitalisation differentiates capacity levels in four categories: optional capacity, essential capacity, exceeded/overwhelmed capacity and coverage service. If a capacity level is categorised as *optional* (segments depicted in white), this means that the segment in question could theoretically be operated by a lower-capacity mode (eg. Trackless Tram in place of train or bus in place of Trackless Tram) without resulting in prohibitive overcrowding.

If a capacity level is categorised as *essential* (bus segments depicted in green, Trackless Tram segments in red and train segments in purple) this means that the capacity of the mode offered on the segment is a good match for the number of travel opportunities converging there, and that a mode of lower capacity than the one in place would either not cope with the transport task or attract a lower public transport mode share (or both).

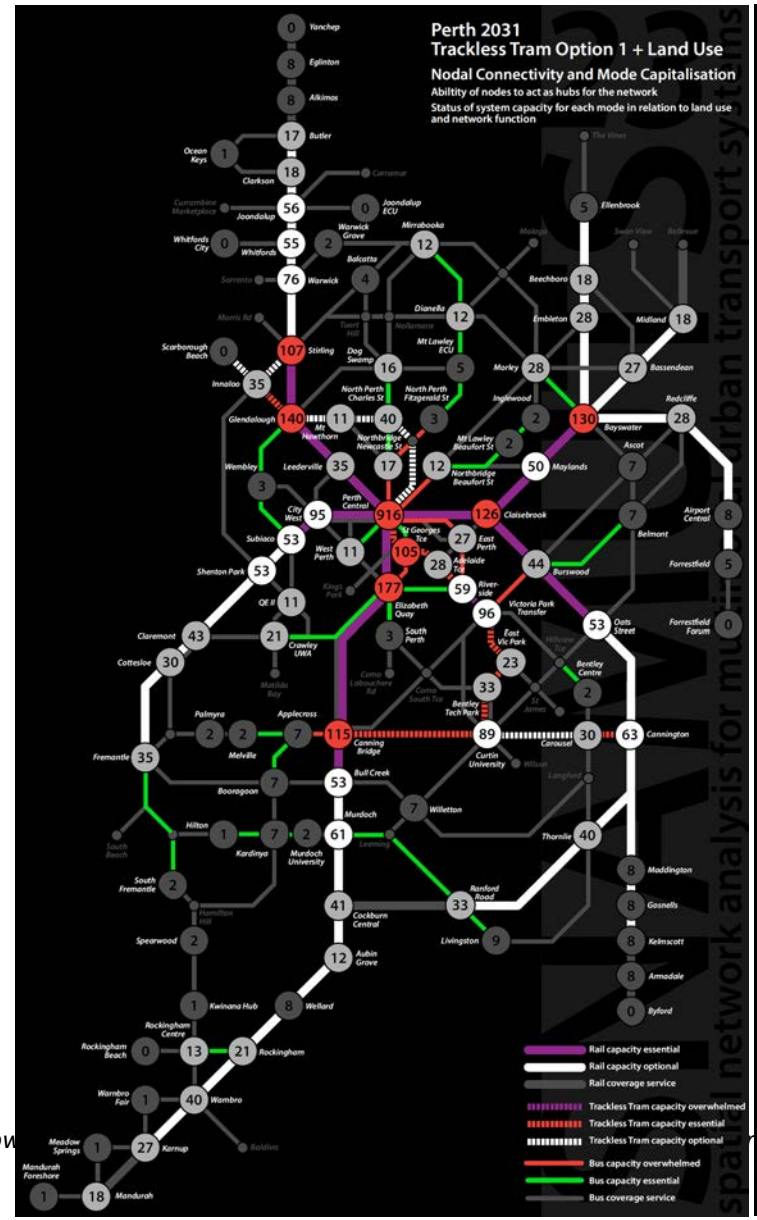
If a capacity level is categorised as *exceeded/overwhelmed* (bus segments depicted in red and Trackless Tram segments in purple), this means that the mode offered on the segment is not capable of providing the capacity needed to serve the travel opportunities converging there, at least as long as walking, cycling, driving or detours along other public transport routes don't offer viable and scalable alternatives to using this particular route segment.

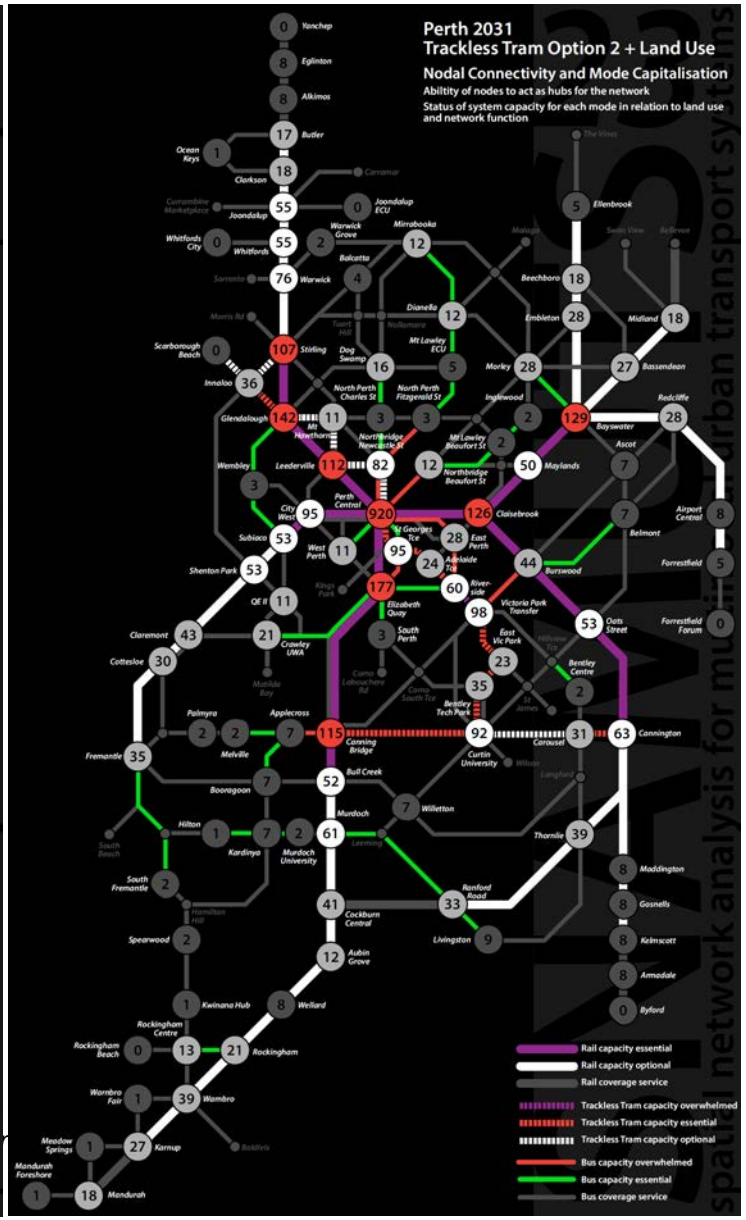
Lastly, segments depicted in grey (on any mode) do not have a network function of moving sizeable numbers of passengers along particular corridors; they are better characterised as a

'coverage service' whose primary rationale is to provide a broad geographical reach for public transport rather than a specific capacity for ridership.[4] Routes or parts of routes fully within this category could conceivably also be operated by non-conventional modes such as open-access autonomous vehicles rather than line-haul public transport if and when such technologies are deployed at equivalent user costs and availability.

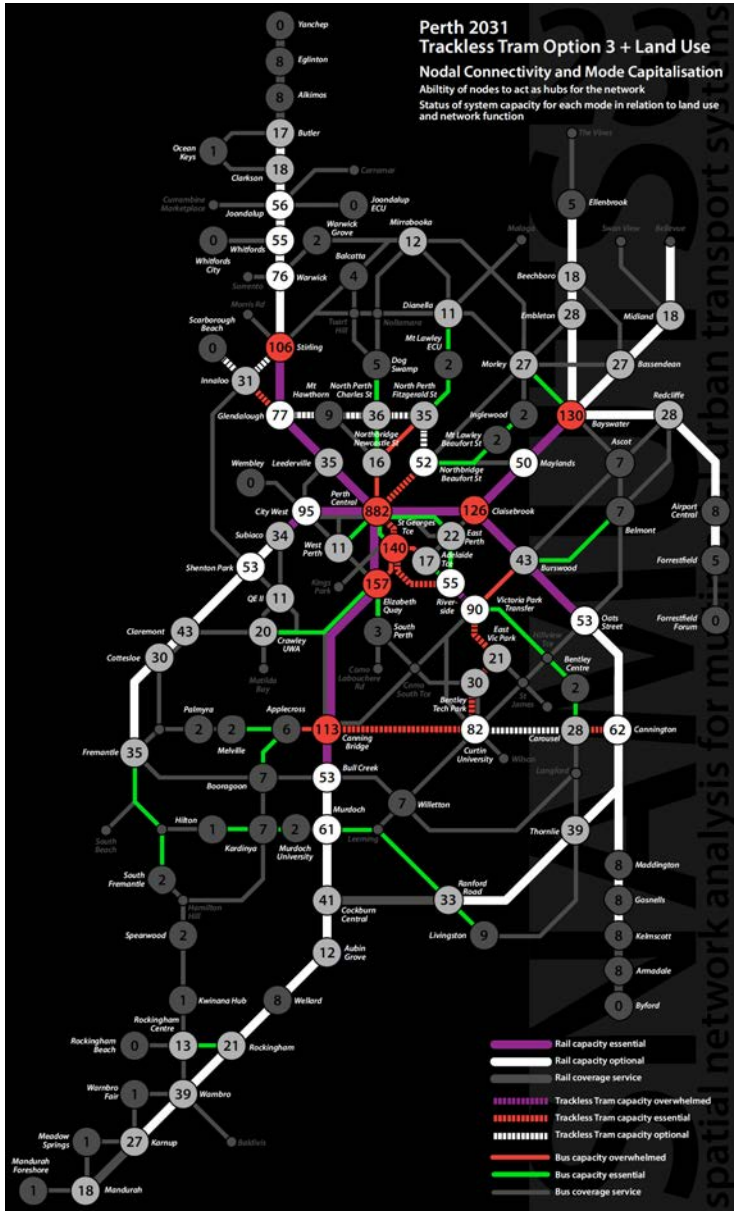
Figures 30-36: *Mode capitalisation diagrams for the 2031 Base scenario and for Trackless Tram Options 1, 2, 3, 4, 5 and X with additional land use intensification*

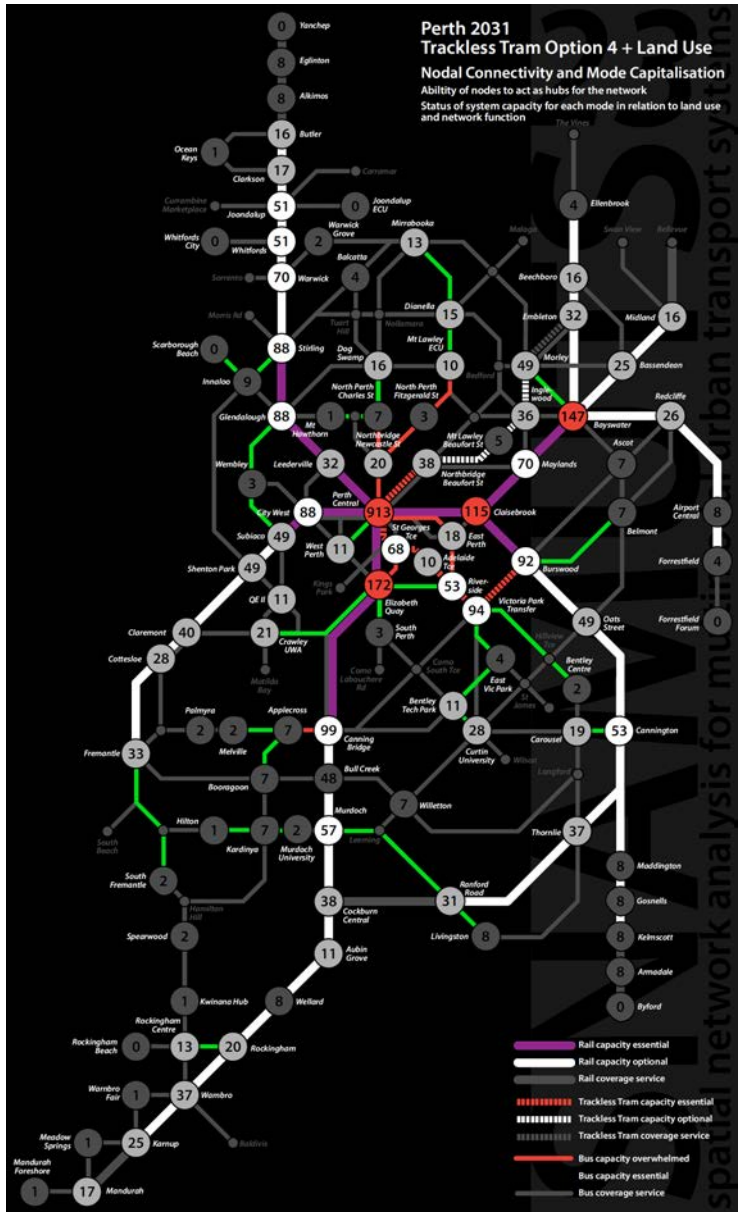
Figures 30-36 illustrate the mode capitalisation index for the 2031 trend scenario and for Options 1, 2, 3, 4, 5 and X, each with land use intensification





[4] Walker J (2012) *Human Transit. How* Island Press, Washington (DC), USA





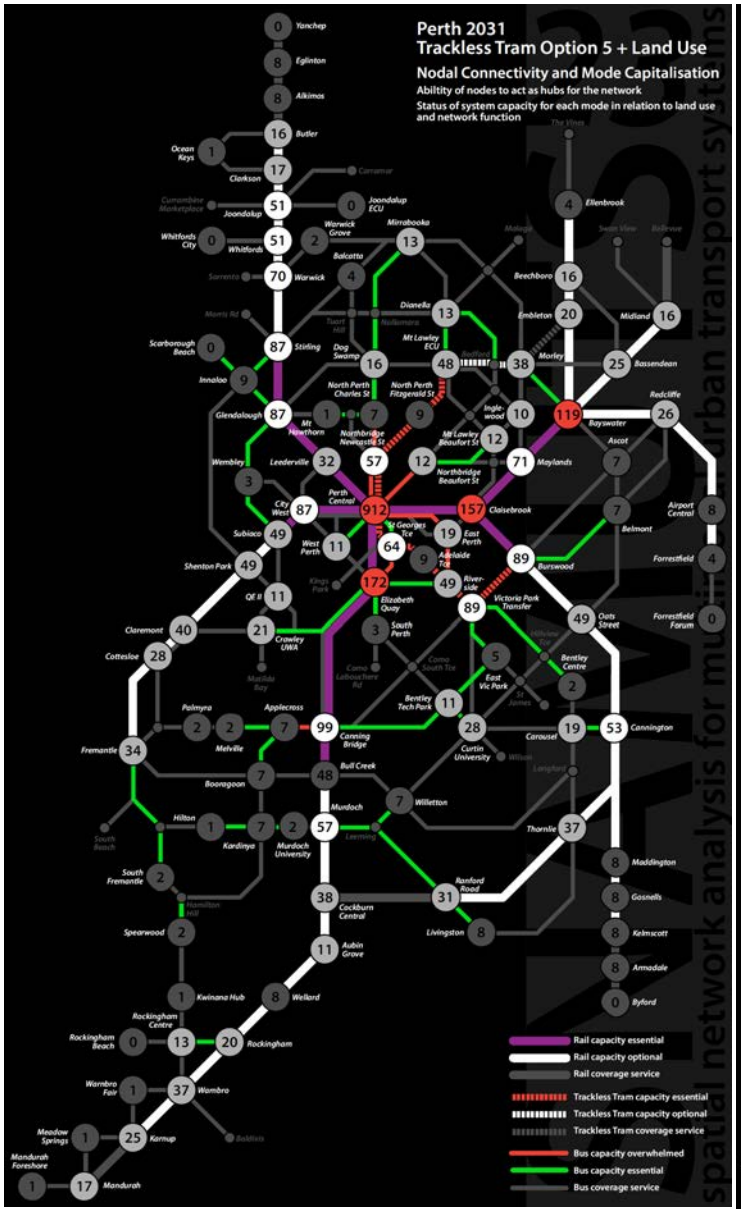
assumptions as detailed above. The 2031 Base analysis shows that buses on the approach routes to the CBD from the south-east (Causeway) and the north (Charles, Fitzgerald and Beaufort Streets), as well as on the principal corridors within the CBD, can be expected to already be overwhelmed with their transport task on trend growth assumptions.

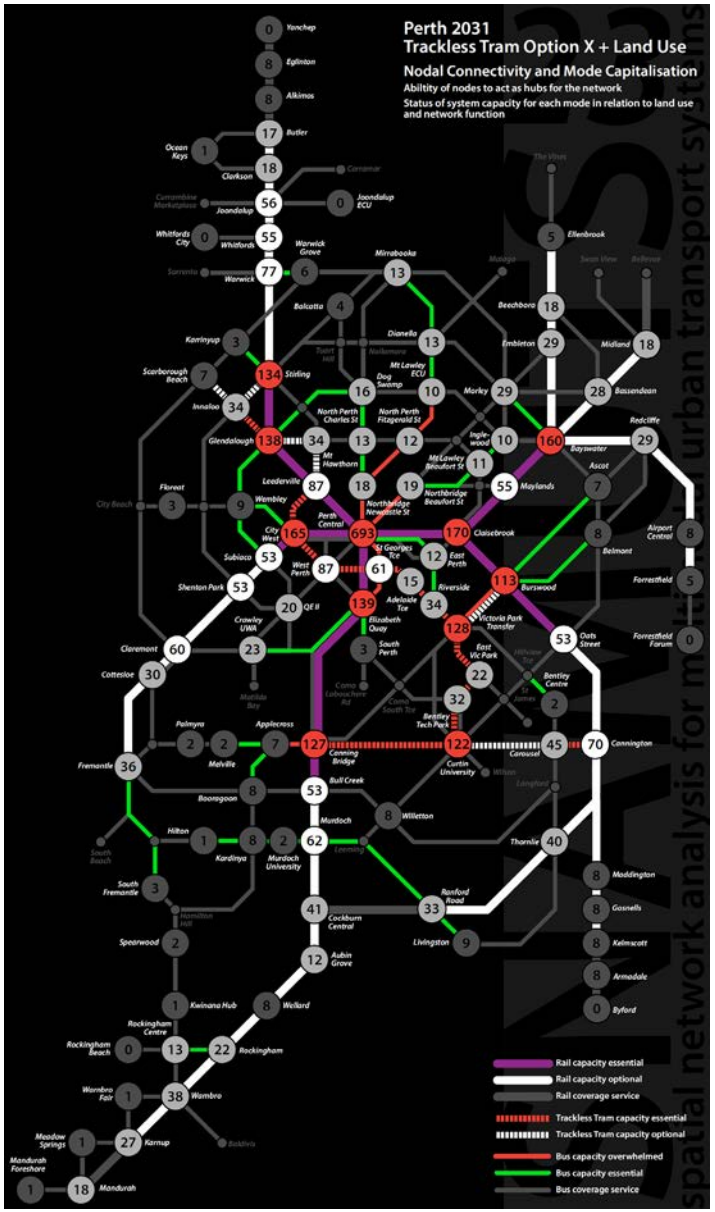
In the Trackless Tram scenarios, this shortfall is addressed successfully on those corridors where Trackless Trams replace or supplement buses. However, in Options 1, 2, 4 and 5, the Wellington Street bus corridor in the CBD remains characterised by an excessive concentration of travel opportunities. Further, in Options 1, 2 and 3 the Swan River crossing at the Causeway moves into a category where even a medium-capacity mode meets its limitations. This suggests that the Trackless

Tram project can delay the need for an additional public transport river crossing at some stage after 2031, but not eliminate it in the face of continuing metropolitan growth.

In each of Options 1, 2, 3 and X, it is conspicuous that the branch between Curtin University and Canning Bridge comes out as medium capacity-worthy and thus stronger than the branch between Curtin University and Carousel-Cannington. Travel times on this section, if routed along Jackson Avenue and Henley Street with only one or two intermediate stops, are low enough to create an attractive feeder service for the growing university precinct as well as the Victoria Park area to and from Perth's busiest heavy rail line at Canning Bridge.

In contrast, the branch line to Cannington is longer and slower and is not attractively located to pull travel opportunities away from the Armadale rail line,





except to and from the Curtin University/Bentley Tech Park area.

In Options 4 and 5, it becomes apparent that the Trackless Tram section between Morley centre and the Morley-Embleton rail interchange does not move beyond the category of a coverage service, or in other words, it fails to attract sufficient travel opportunities to create a significant transit corridor in this location. While the concept of creating an attractive transfer connection between Ellenbrook and Morley in the absence of a rail station located at Morley centre proper is plausible, in reality the limited concentration of residents and jobs at either end as well as the relatively long travel times between these two centres conspire to make this link relatively insignificant in Perth's metropolitan-wide public transport network.

SNAMUTS composite index

The final index presented here is composed of results from the six component indicators of closeness centrality, degree centrality, 30-minute contour catchment, nodal betweenness, nodal resilience and nodal connectivity. Each nodal indicator result except resilience is calibrated on a scale of 0 to 12 for a maximal score of 60; additionally, deductions apply for negative nodal resilience results. The outcome is illustrated as a scale map in traffic light colours depicting the walkable catchments of each SNAMUTS activity node. This indicator has primarily been designed for visualisation purposes; while the numeric results remain comparable from one scenario to the next, they should be used with caution as their levels are determined by the somewhat arbitrary conversion formulas and weighting of each of the more precision-based component indicators.

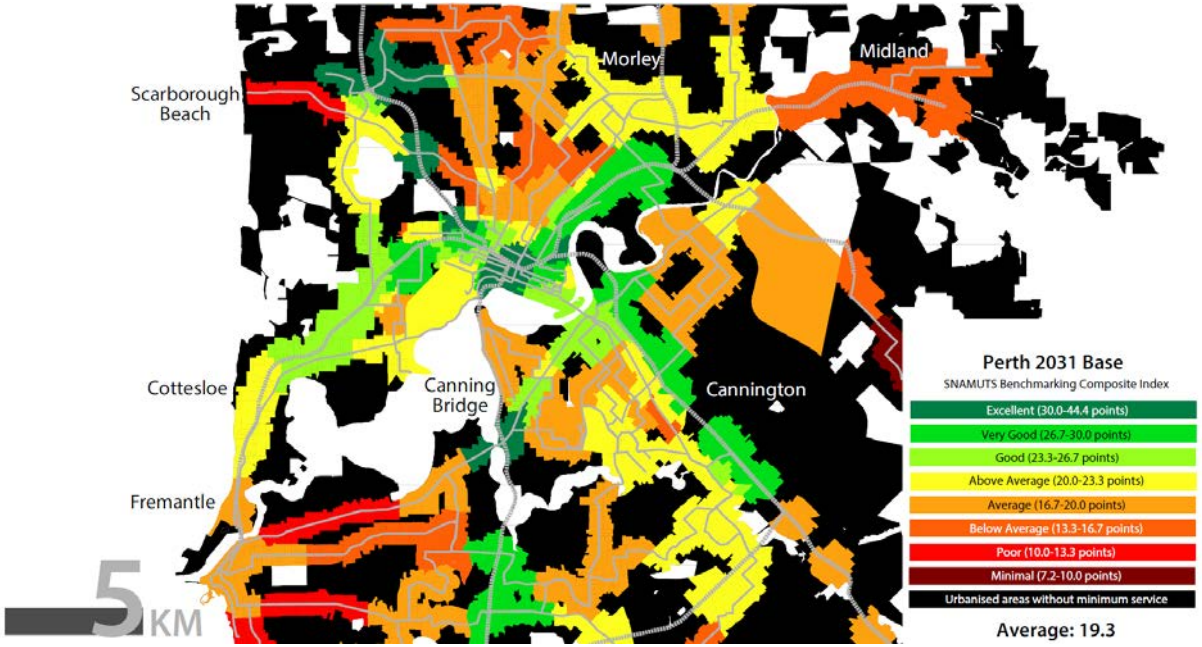


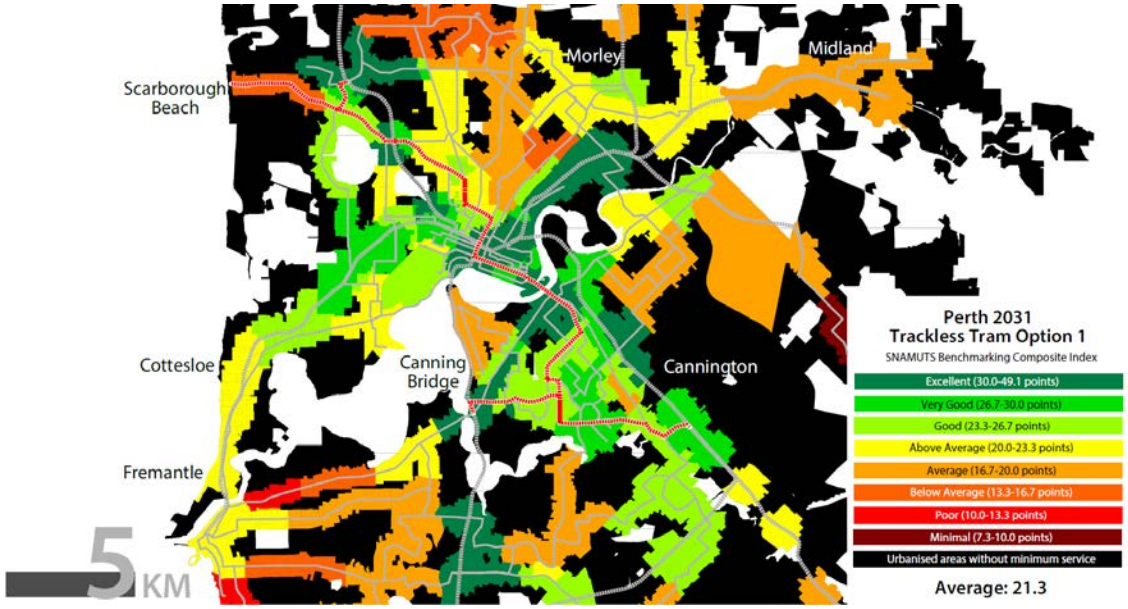
Figure 38 (2031 Base network) illustrates some of the shortfalls of Perth's public transport network on its current development trajectory that the

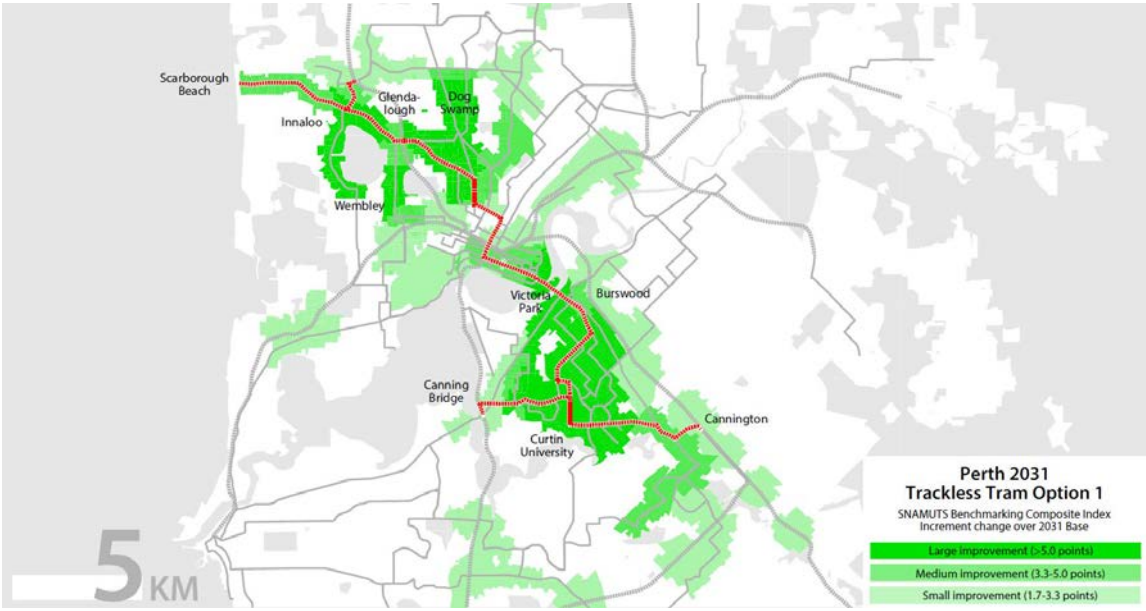
introduction of a medium-capacity mode such as the Trackless Tram is trying to address. These include the achievement of a top score in the elongated CBD only within walking distance of Perth Central and Elizabeth Quay stations, while the western and eastern ends drop significantly in accessibility performance. Elsewhere in inner Perth, there is a considerable performance gap between the rail station precincts and areas away from the rail lines; this becomes particularly obvious in the inner north where accessibility performance all but falls off a cliff at a mere kilometre's distance from the CBD, and in the inner south-east where the gap between the Mandurah and Armadale train lines leaves a sizeable area of underperformance in Victoria Park and Bentley.

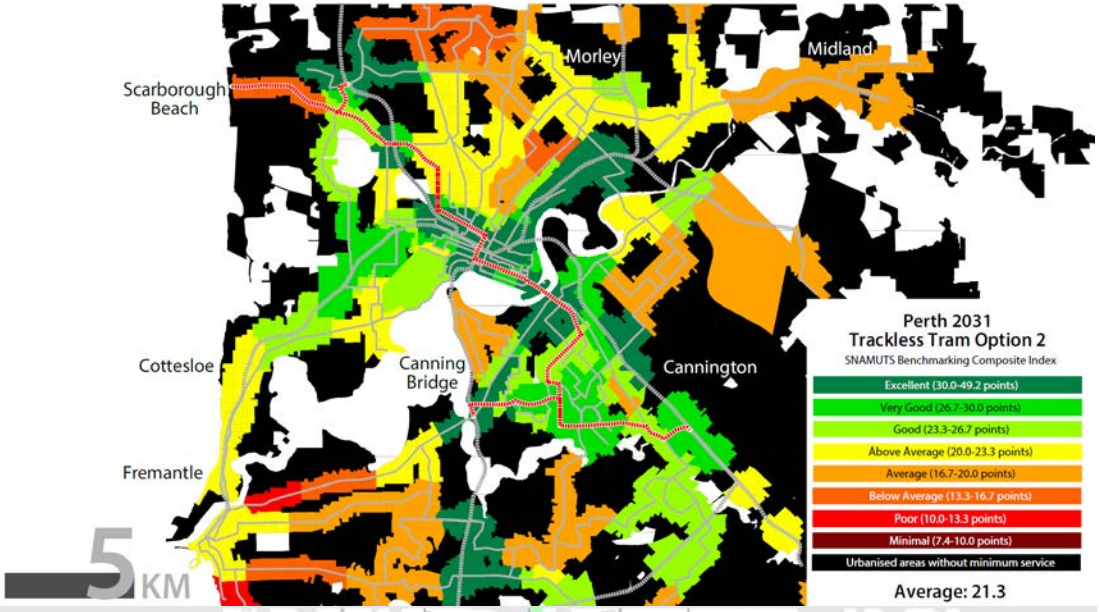
Figures 39-50 present a composite index map for each of Options 1, 2, 3, 4, 5 and X, as well as a map showing the increment of improvement for each activity node catchment, allowing to localise the areas of greatest additional benefit in each scenario at a glance.

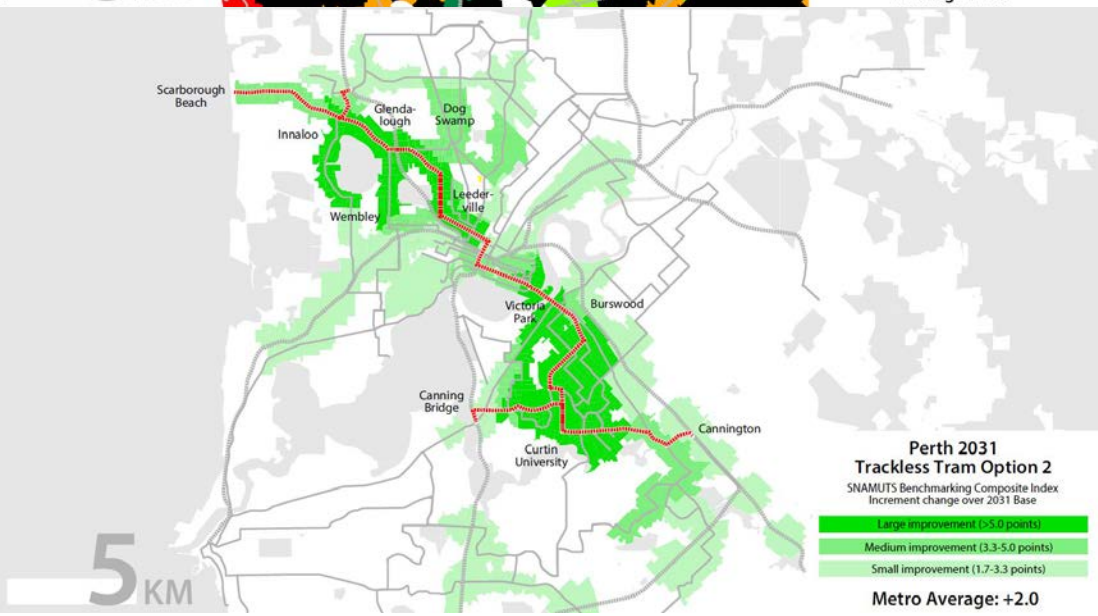
In all Trackless Tram scenarios, it is conspicuous that the gains in accessibility performance are relatively modest in the CBD area, despite the prominence of the CBD alignment of the new mode: the greatest beneficiaries tend to be located in inner suburbs away from the heart of the city. This is not an undesired outcome: as discussed above, there is a greater need for accessibility improvements beyond the central city than within it.

In Options 1, 2, 4, 5 and X, some of the greatest improvement in accessibility performance can be traced





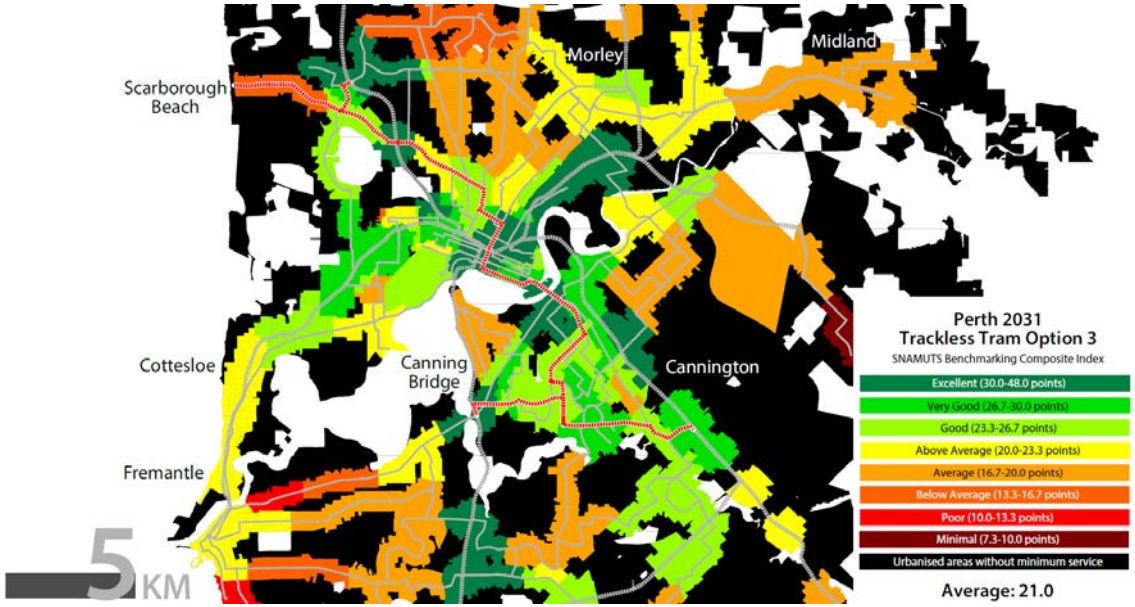




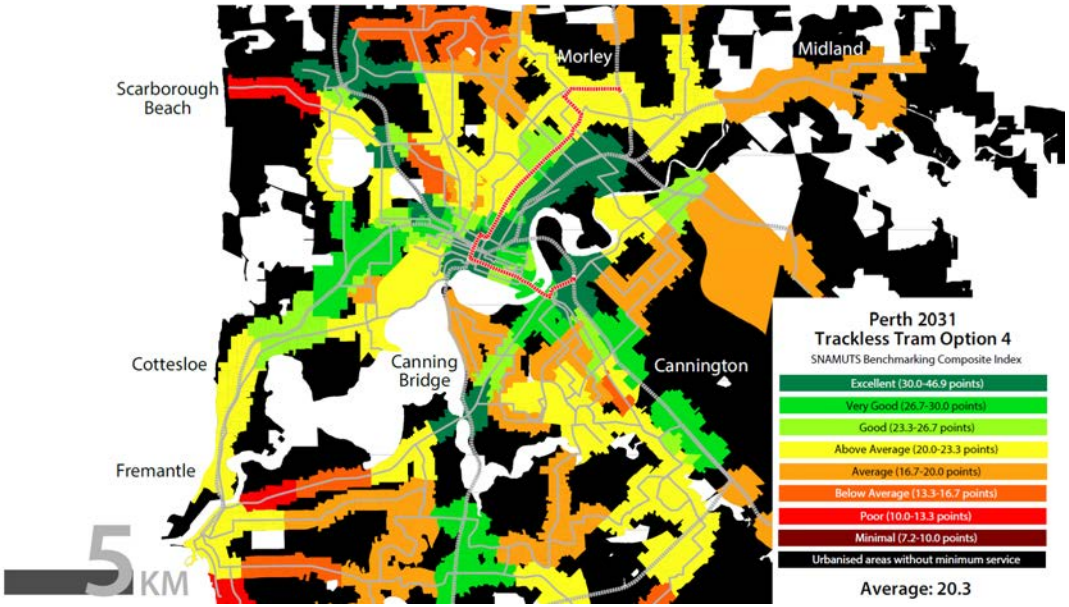
to the additional orbital bus routes penetrating into new areas where public transport access had been deficient: namely Dog Swamp and Mount Lawley in Options 1, 2 and X, and Wembley in all five options.

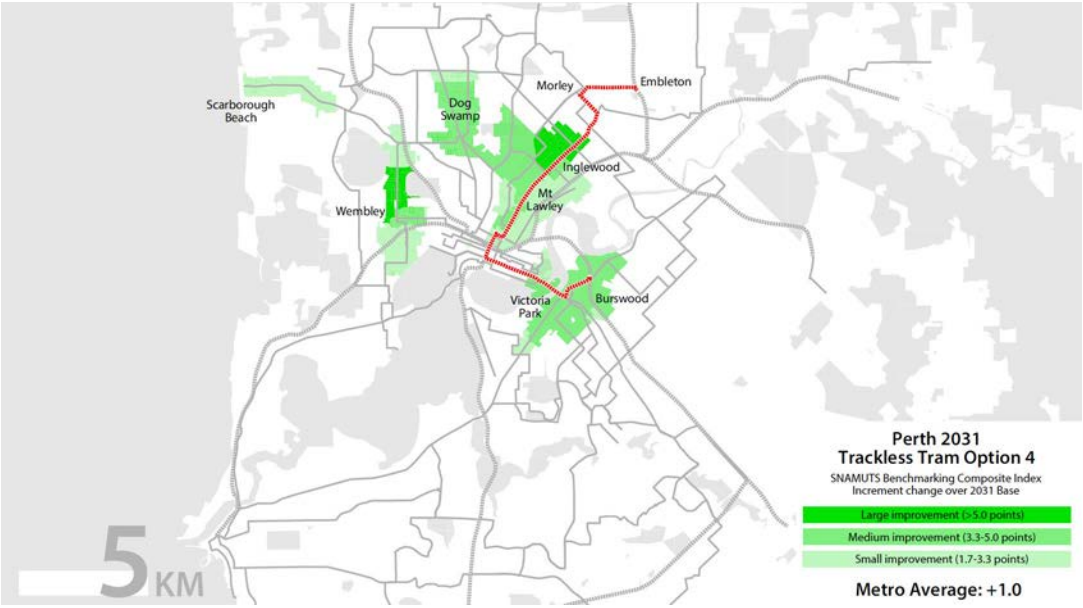
In Option 4 and to a lesser degree Option 5, it is remarkable how there is very little movement in the accessibility performance of Morley, even though providing a medium-capacity link to this centre forms a major part of the rationale for these Trackless Tram alignments. Neither scenario, however, contains an additional land use intensification assumption for this particular area.

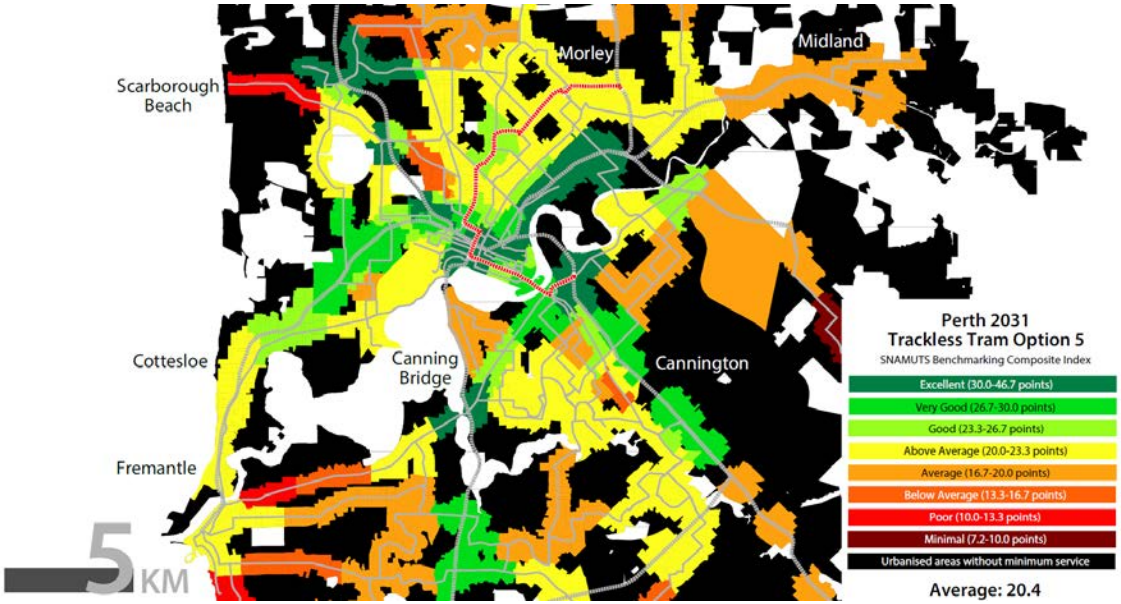
Figures 38-50: *SNAMUTS Composite Index and Composite Increment Change for the 2031 Trend and Trackless Tram Options 1, 2, 3, 4, 5 and X with additional land use intensification*

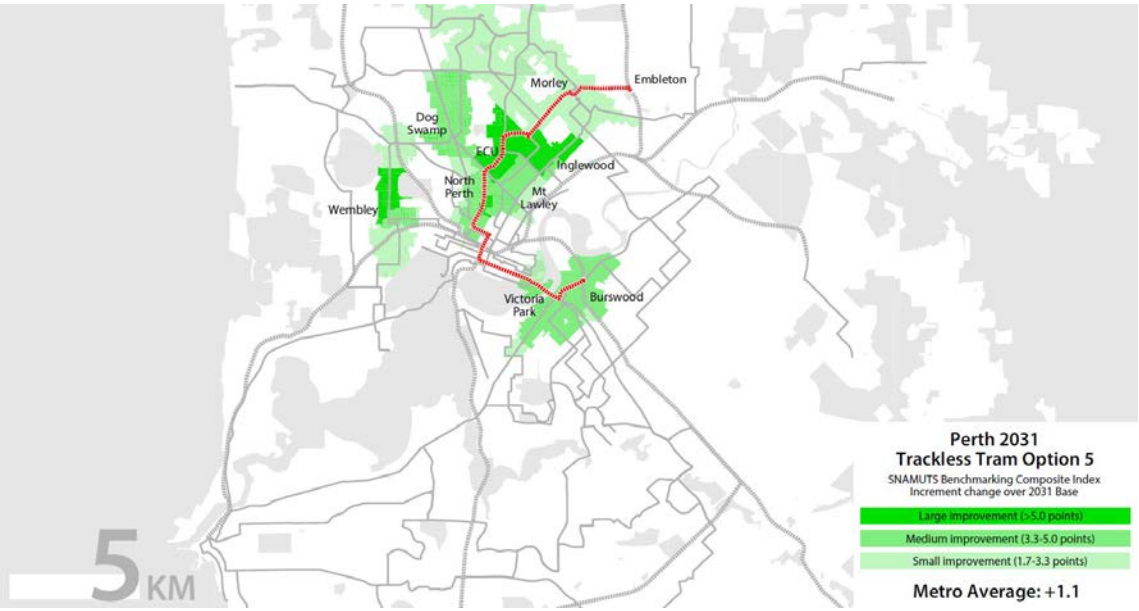

Scarborough Beach
Morley
Midland
Cottesloe
Canning Bridge
Cannington
Fremantle
5 KM
Perth 2031
Trackless Tram Option 3
SNAMUTS Benchmarking Composite Index
Excellent (30.0-48.0 points)
Very Good (26.7-30.0 points)
Good (23.3-26.7 points)
Above Average (20.0-23.3 points)
Average (16.7-20.0 points)
Below Average (13.3-16.7 points)
Poor (10.0-13.3 points)
Minimal (7.3-10.0 points)
Urbanised areas without minimum service
Average: 21.0

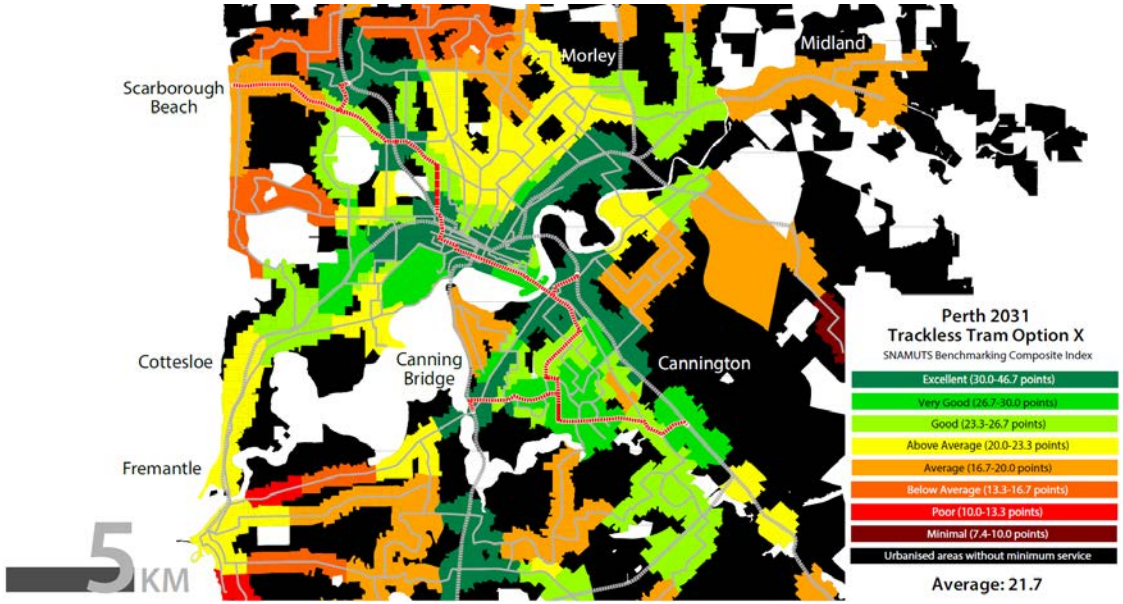

Scarborough Beach
Glenda-lough
Innaloo
North Perth
Victoria Park
Burswood
Canning Bridge
Curtin University
Cannington
5 KM
Perth 2031
Trackless Tram Option 3
SNAMUTS Benchmarking Composite Index
Increment change over 2031 Base
Large improvement (>5.0 points)
Medium improvement (3.3-5.0 points)
Small improvement (1.7-3.3 points)
Metro Average: +1.7

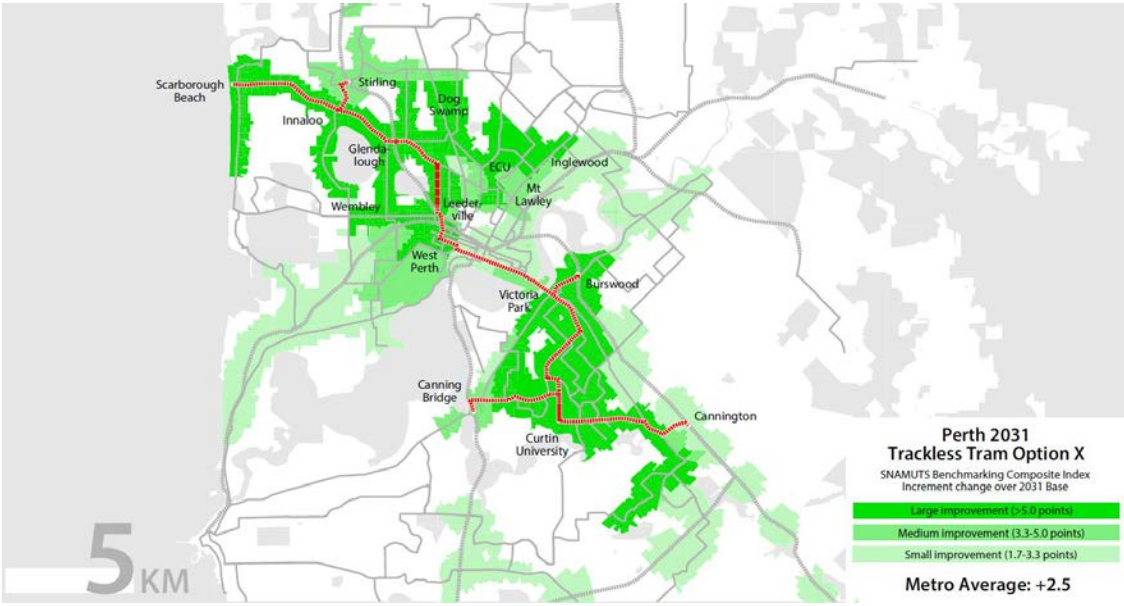

Scarborough Beach
Morley
Midland
Cottesloe
Canning Bridge
Cannington
Fremantle
5 KM
Perth 2031
Trackless Tram Option 4
SNAMUTS Benchmarking Composite Index
Excellent (30.0-46.9 points)
Very Good (26.7-30.0 points)
Good (23.3-26.7 points)
Above Average (20.0-23.3 points)
Average (16.7-20.0 points)
Below Average (13.3-16.7 points)
Poor (10.0-13.3 points)
Minimal (7.2-10.0 points)
Urbanised areas without minimum service
Average: 20.3


Scarborough Beach
Dog Swamp
Morley
Embleton
Inglewood
Mt Lawley
Wembley
Victoria Park
Burswood
5 KM
Perth 2031
Trackless Tram Option 4
SNAMUTS Benchmarking Composite Index
Increment change over 2031 Base
Large improvement (>5.0 points)
Medium improvement (3.3-5.0 points)
Small improvement (1.7-3.3 points)
Metro Average: +1.0


Scarborough Beach
Morley
Midland
Cottesloe
Canning Bridge
Cannington
Fremantle
5 KM
Perth 2031
Trackless Tram Option 5
SNAMUTS Benchmarking Composite Index
Excellent (30.0-46.7 points)
Very Good (26.7-30.0 points)
Good (23.3-26.7 points)
Above Average (20.0-23.3 points)
Average (16.7-20.0 points)
Below Average (13.3-16.7 points)
Poor (10.0-13.3 points)
Minimal (7.2-10.0 points)
Urbanised areas without minimum service
Average: 20.4


Morley
Embleton
Dog Swamp
FCU
Inglewood
North Perth
Mt Lawley
Wembley
Victoria Park
Burswood
5 KM
Perth 2031
Trackless Tram Option 5
SNAMUTS Benchmarking Composite Index
Increment change over 2031 Base
Large improvement (>5.0 points)
Medium improvement (3.3-5.0 points)
Small improvement (1.7-3.3 points)
Metro Average: +1.1


Scarborough Beach
Morley
Midland
Cottesloe
Canning Bridge
Cannington
Fremantle
5 KM
Perth 2031
Trackless Tram Option X
SNAMUTS Benchmarking Composite Index
Excellent (30.0-46.7 points)
Very Good (26.7-30.0 points)
Good (23.3-26.7 points)
Above Average (20.0-23.3 points)
Average (16.7-20.0 points)
Below Average (13.3-16.7 points)
Poor (10.0-13.3 points)
Minimal (7.4-10.0 points)
Urbanised areas without minimum service
Average: 21.7


Scarborough Beach
Stirling
Dog Swamp
Innaloo
Glendalough
ECU
Inglewood
Mt Lawley
Wembley
Leederville
West Perth
Victoria Park
Burswood
Canning Bridge
Cannington
Curtin University
5 KM
Perth 2031
Trackless Tram Option X
SNAMUTS Benchmarking Composite Index
Increment change over 2031 Base
Large improvement (>5.0 points)
Medium improvement (3.3-5.0 points)
Small improvement (1.7-3.3 points)
Metro Average: +2.5

SECTION 5
Combination scenarios

This last step of our analysis concerns two further scenarios that have been developed in the process of consultations both with project stakeholders as well as internally within the project team following the second workshop in December 2019.

Option Y is a combination of Options 4 and X discussed in the previous section. Option Z contains Option Y and also adds a second Trackless Tram corridor through the CBD along Wellington Street, allowing the Swan River crossing at the Causeway to be freed from buses and used exclusively by Trackless Trams. Option Z also contains a further branch route from West Perth along Thomas Street and Winthrop Avenue to the QE II medical centre and UWA's Crawley campus. Both scenarios are based on the same assumptions of land use intensification over and above the 2031 trend as those described in the previous section. They are perhaps best interpreted as an intermediate step (Option Y), following the starter line (Option 4 or X), towards a medium-term target network (Option Z) for Trackless Trams in Perth.

Operational and service patterns have been determined iteratively, with the aim of arriving at (mostly) positive segmental resilience results along all Trackless Tram routes, and to remain within the service intensity envelope of all other scenarios (ie. not or only marginally exceeding the total number of public transport vehicles in simultaneous revenue operation across metropolitan Perth in the 2031 Trend and in all other scenarios previously discussed).

In Option Y (Figure 51), five Trackless Tram lines operate every 10 minutes each during the weekday interpeak period:

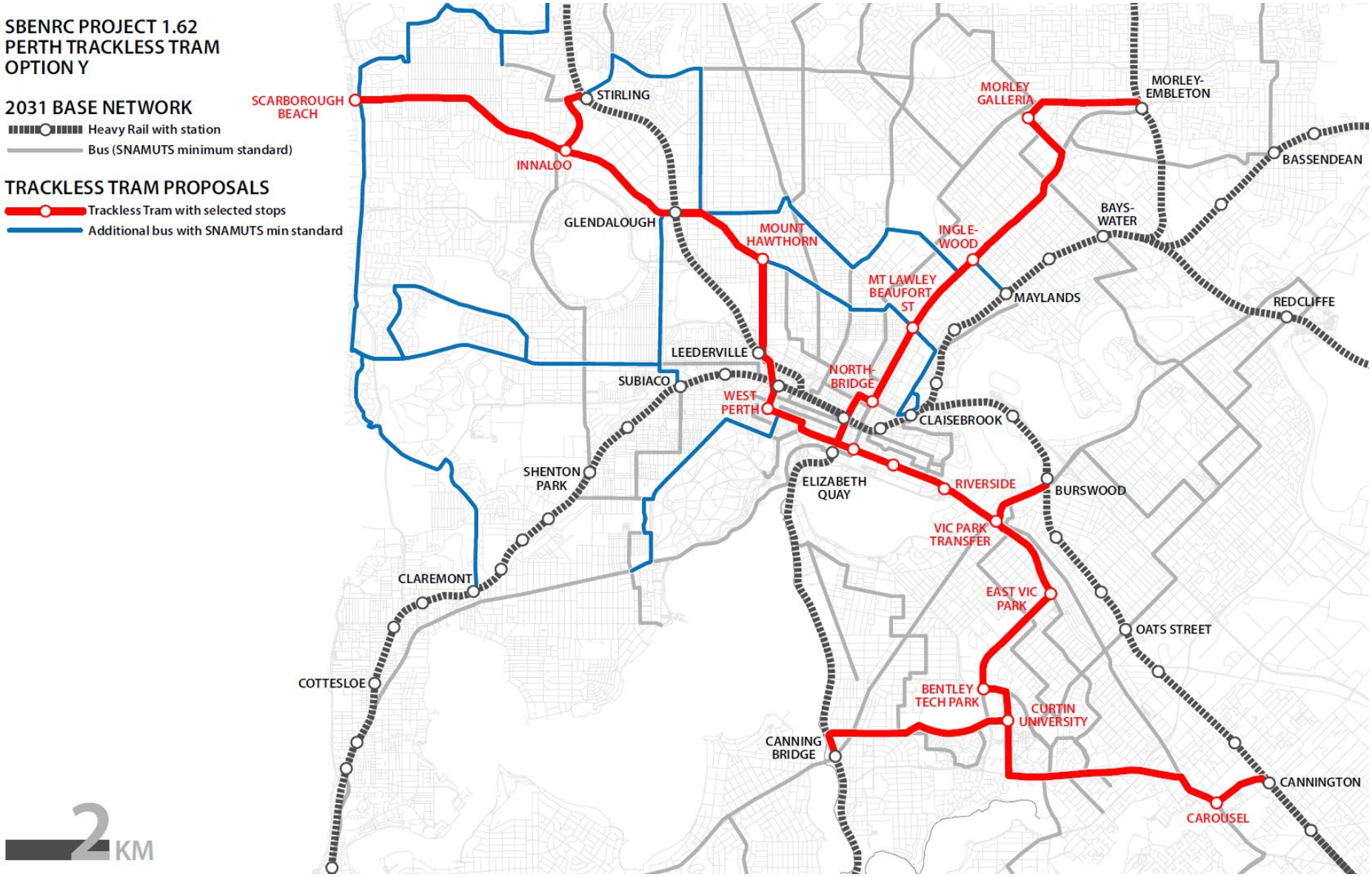
- Route Y1: Scarborough Beach – Cannington
- Route Y2: Stirling – Canning Bridge (peak hours only between Glendalough and Leederville)
- Route Y3: Canning Bridge – Cannington
- Route Y4: Morley (Embleton) – Burswood
- Route Y5: Morley (Centre) – Leederville

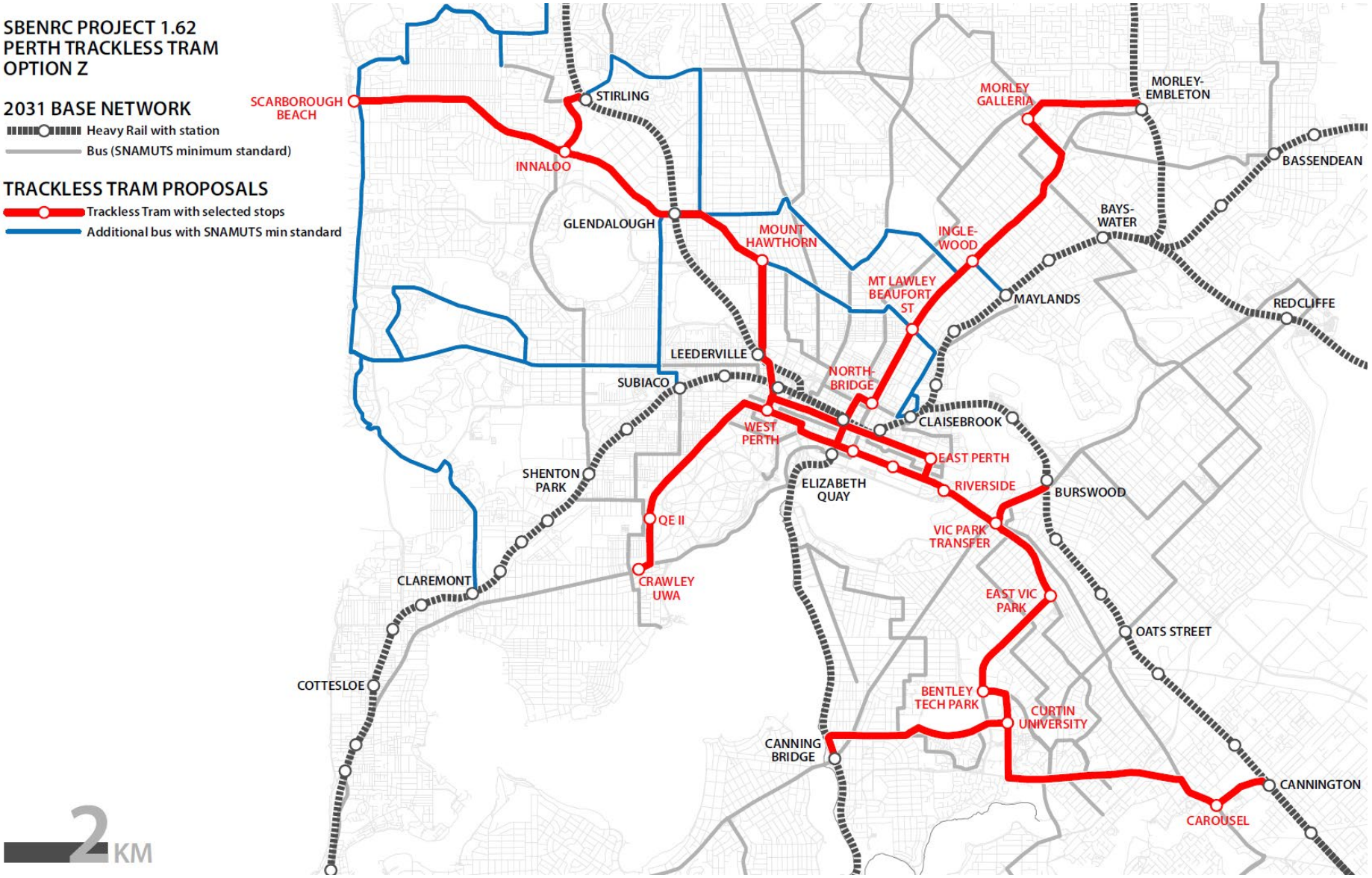
In Option Z (Figure 52), six Trackless Tram lines operate every 8 minutes each during the weekday interpeak period:

- Route Z1: Scarborough Beach – Cannington via St Georges Terrace
- Route Z2: Stirling – Canning Bridge via Wellington Street (peak hours only between Glendalough and Leederville)
- Route Z3: Canning Bridge – Cannington
- Route Z4: Morley (Embleton) – Burswood via St Georges Terrace
- Route Z5: Morley (Centre) – Crawley UWA via St Georges Terrace
- Route Z6: Burswood – Crawley UWA via Wellington Street

In both scenarios, the additional bus routes from Option X have been retained (though the orbital route from Subiaco via Glendalough, ECU Mount Lawley and Inglewood now terminates at Maylands, not Bayswater). Option Y also retains ten buses per hour per direction along the Causeway and Wellington Street (routes 930 and 220). In Option Z these terminate at Burswood. Option Z further merges the red, yellow and green CAT routes into a single line linking Elizabeth Quay and Claisebrook via West Perth, Hay and Murray Streets, and reduces its daytime frequency to every 10 minutes.

Figures 51, 52: *Overview of route variations for a Trackless Tram starter line in Perth (Options Y and Z)*

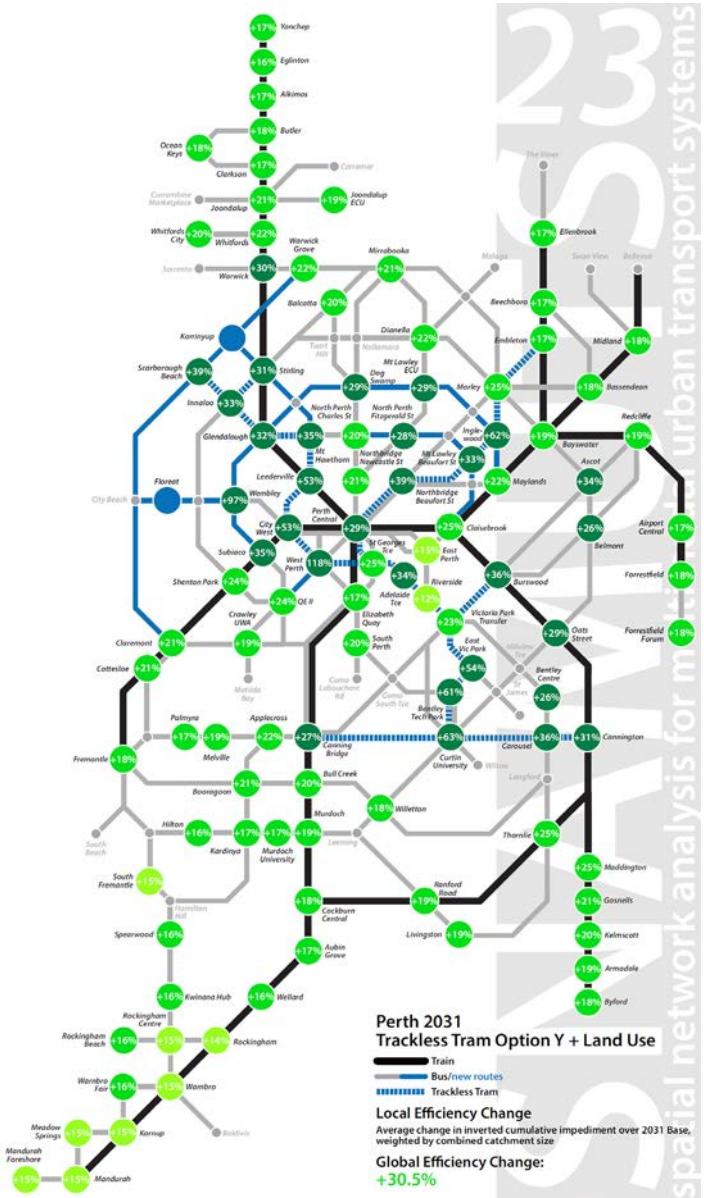

SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION Y
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Additional bus with SNAMUTS min standard
SCARBOROUGH BEACH
STIRLING
INNALOO
GLENDALOUGH
MOUNT HAWTHORN
MORLEY GALLERIA
MORLEY-EMBLETON
BASSENDEAN
BAYS-WATER
INGLE-WOOD
MT LAWLEY BEAUFORT ST
MAYLANDS
REDCLIFFE
LEEDERVILLE
SUBIACO
NORTH-BRIDGE
WEST PERTH
CLAISEBROOK
SHENTON PARK
ELIZABETH QUAY
RIVERSIDE
BURSWOOD
VIC PARK TRANSFER
CLAREMONT
EAST VIC PARK
OATS STREET
COTTESLOE
BENTLEY TECH PARK
CURTIN UNIVERSITY
CANNING BRIDGE
CANNINGTON
CAROUSEL
2 KM

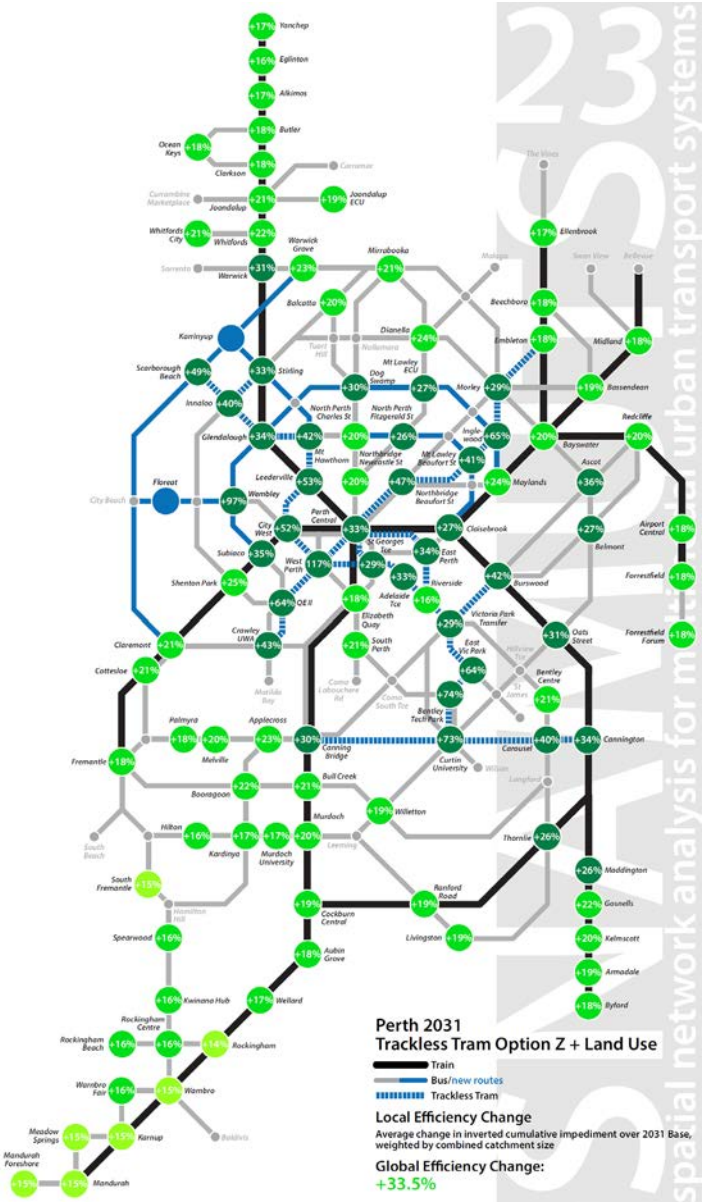

SBENRC PROJECT 1.62
PERTH TRACKLESS TRAM
OPTION Z
2031 BASE NETWORK
Heavy Rail with station
Bus (SNAMUTS minimum standard)
TRACKLESS TRAM PROPOSALS
Trackless Tram with selected stops
Additional bus with SNAMUTS min standard
SCARBOROUGH BEACH
STIRLING
INNALOO
GLENDALOUGH
MOUNT HAWTHORN
LEEDERVILLE
SUBIACO
SHENTON PARK
CLAREMONT
COTTESLOE
QE II
CRAWLEY UWA
WEST PERTH
NORTH-BRIDGE
ELIZABETH QUAY
CLAISEBROOK
EAST PERTH
RIVERSIDE
VIC PARK TRANSFER
EAST VIC PARK
BENTLEY TECH PARK
CURTIN UNIVERSITY
CANNING BRIDGE
CAROUSEL
CANNINGTON
OATS STREET
BURSWOOD
MAYLANDS
MT LAWLEY BEAUFORT ST
INGLE-WOOD
MORLEY GALLERIA
MORLEY-EMBLETON
BAYS-WATER
BASSENDEAN
REDCLIFFE
2 KM

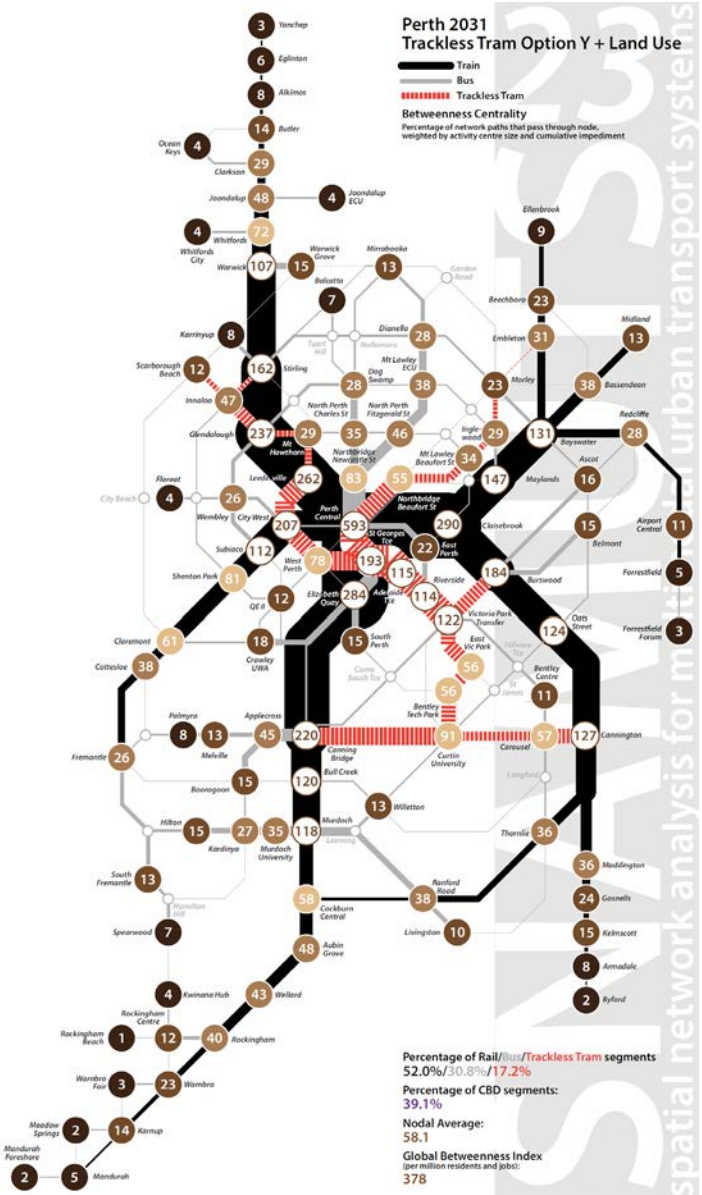
Efficiency change

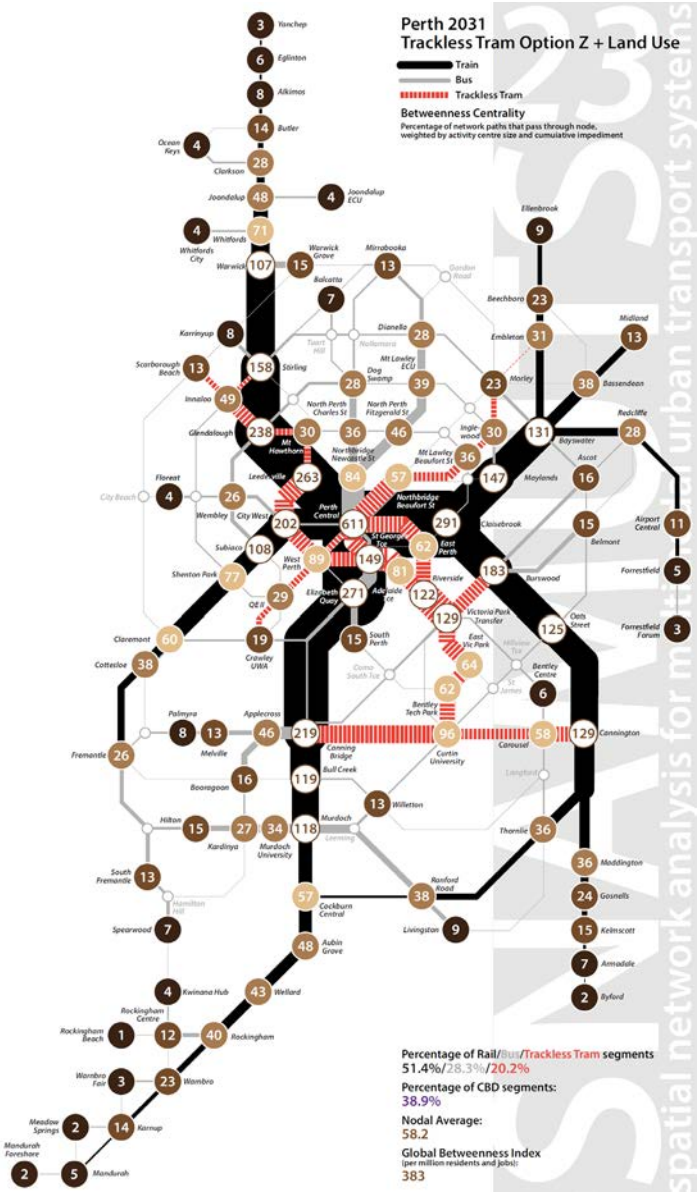
Figures 53 and 54 show the efficiency change network diagrams for Options Y and Z (see Section 2 for a description of this index). Across metropolitan Perth, the land use-public transport system improves in accessibility by more than 30% (Option Y) or 33% (Option Z), a further step up from the 14% improvement in Option 4 + LU and 27% in Option X + LU (Table 4). In both scenarios and due to both the Trackless Tram corridors and the additional connecting orbital bus routes, these benefits spread quite evenly across Perth's inner area, though in Option Y a relative weakness persists in the eastern half of the CBD around the Wellington Street bus corridor.

Figures 53, 54: *SNAMUTS efficiency change network diagrams for Trackless Tram Options Y and Z over the 2031 Trend*









Betweenness centrality

Figures 55, 56: *SNAMUTS betweenness centrality index for Trackless Tram Options Y and Z*

Figures 55 and 56 show the betweenness network diagrams for Options Y and Z (see Section 2 for a description of this index). The share of public transport travel opportunities across metropolitan Perth services by the Trackless Tram climbs from 6% (Option 4 + LU) or 14% (Option X + LU) to 17% in Option Y and a remarkable 20% in Option Z, suggesting that Trackless Trams will already occupy a mature-sized role in Perth's modal mix if this medium-term target network can be implemented.

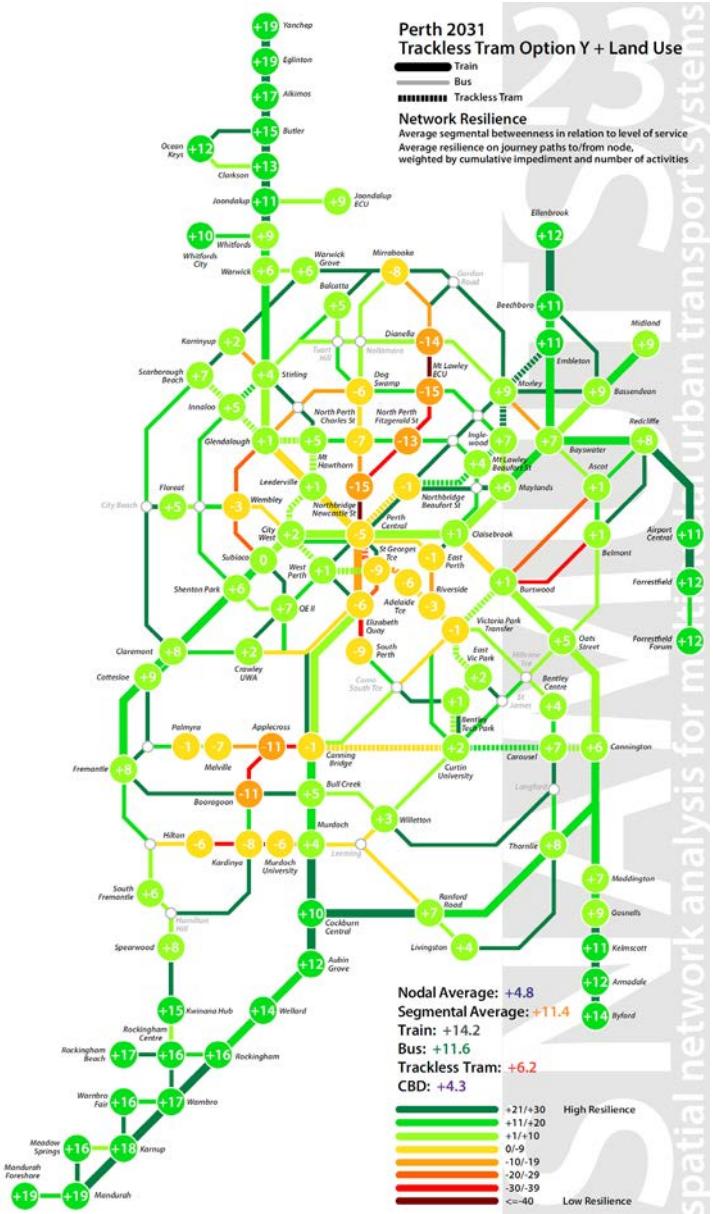
Option Z illustrates that the parallel CBD corridors in St Georges/ Adelaide Terrace and Wellington Street will take on similar network significance in the eastern half of the CBD, while in the western half, the corridor along St Georges Terrace and Hay Street clearly dominates.

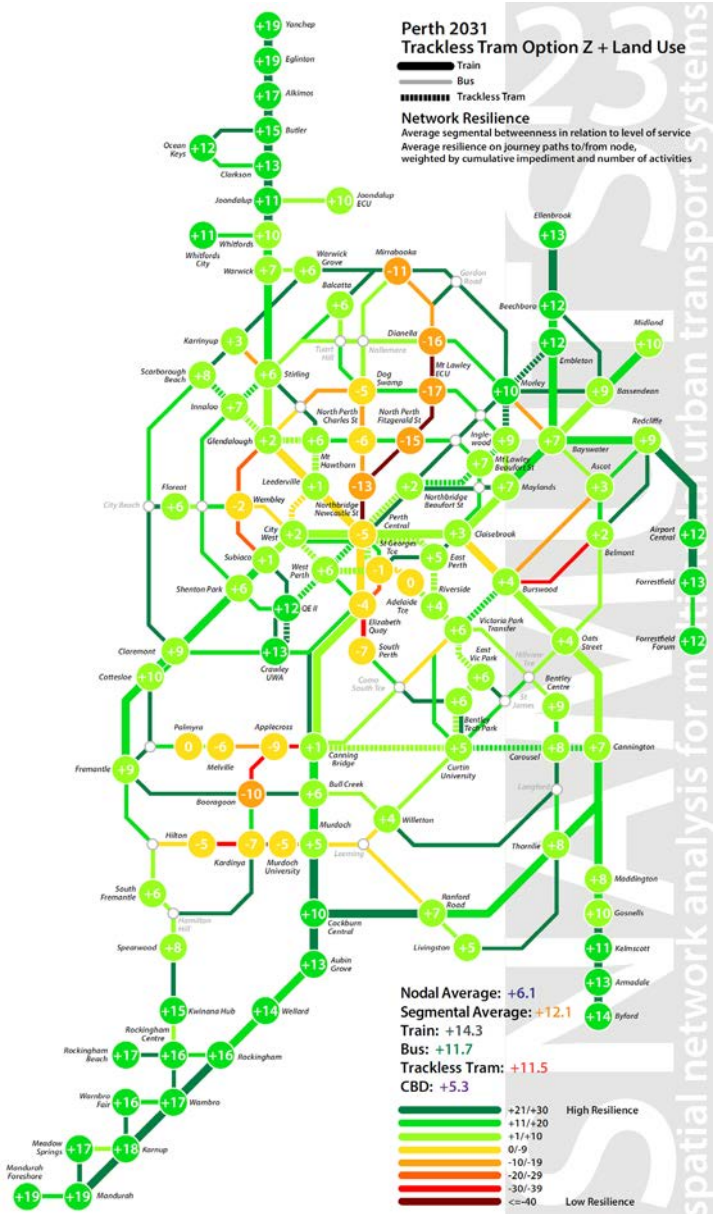
In both scenarios, the weakest Trackless Tram segment can be found between Morley centre and the Embleton rail interchange, suggesting that without an ambitious urban intensification strategy in this area, it will be hard to justify the infrastructure investment associated with taking the Trackless Tram beyond Morley centre.

Network resilience

Figures 57, 58: *SNAMUTS network resilience index for Trackless Tram Options Y and Z*

Figures 57 and 58 show the resilience performance of Perth's public transport network in Trackless Tram Options Y and Z (see Section 2 for a description of this index). Both scenarios reverse the decline particularly in CBD resilience observed in Option X (Table 4). Option Z also addresses the poor resilience that remains in Option Y's Wellington Street bus corridor by converting it to Trackless Tram operation.





However, both maps also illustrate some remaining areas on Perth's public transport network where the service offer will likely fail the transport task inherent in the land use-transport system, and whose poor resilience performance suggests the need for further Trackless Tram (or other medium-capacity mode) conversions of bus routes in the longer-term-future, beyond the horizon of this study. These concern in particular the Belmont area east of the Burswood interchange, the Applecross-Booragoon area west of the Canning Bridge interchange, the Fitzgerald Street-Alexander Drive corridor between central Perth and Mirrabooka, the inner western orbital link between Glendalough and Subiaco, and the river crossing between central Perth and South Perth.

Table 4: *Overview of average SNAMUTS indicator results for Trackless Tram Options 4, X, Y and Z including additional land use assumptions, and the 2031 Trend network (without Trackless Trams)*

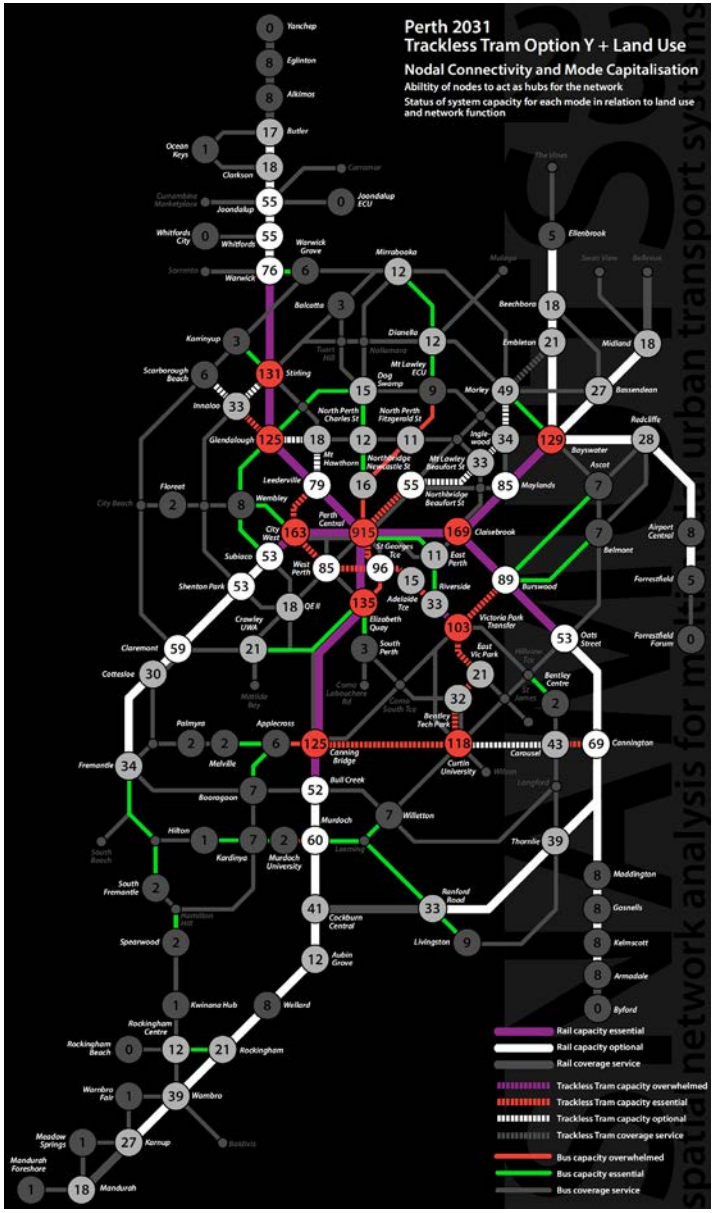
2031 SNAMUTS *23R*	Trend	Option 4 + LU	Option X + LU	Option Y + LU	Option Z + LU
Average Closeness Centrality Metropolitan Perth	47.8	47.1	46.6	46.4	46.0
Average Degree Centrality Metropolitan Perth	1.01	0.99	0.98	0.98	0.98
Average 30-min Contour Catchment Metropolitan Perth	14.6%	16.2%	18.2%	18.7%	19.0%
Network Coverage (percentage of metropolitan residents and jobs)	52.0%	54.0%	59.7%	60.0%	60.0%
Average Nodal Betweenness Metropolitan Perth	50.8	51.7	57.7	58.1	58.2
Average Nodal Resilience Metropolitan Perth	+3.4	+4.8	+4.0	+4.8	+6.1

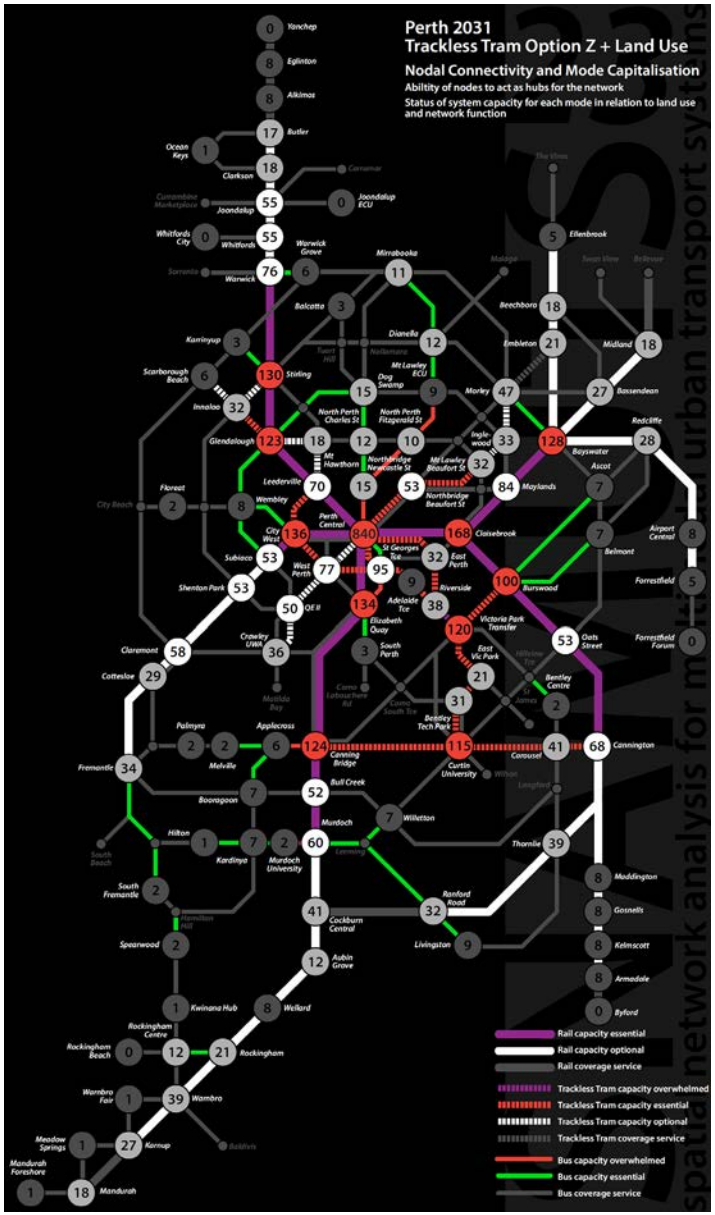
2031 SNAMUTS *23R*	Trend	Option 4 + LU	Option X + LU	Option Y + LU	Option Z + LU
Average Nodal Resilience CBD	+2.5	+5.7	-0.5	+4.3	+5.3
Average Nodal Connectivity Metropolitan Perth	31	34	38	40	40
Global Efficiency Change Metropolitan Perth		+14.0%	+27.0%	+30.5%	+33.5%
Average SNAMUTS Composite Score Metropolitan Perth	19.3	20.3	21.7	21.9	22.1

Mode capitalisation

Figures 59 and 60 show the mode capitalisation network diagrams for Options Y and Z (see section 4 for a description of this index). In Option Z, they illustrate how all Trackless Tram segments south of the Swan River and within the eastern half of the CBD fall into the 'essential' category – meaning that should the aspirational level of urban intensification materialise, operation of these routes by a bus system would provide insufficient capacity to serve the travel opportunities generated.

In other parts of the network, the picture is patchier: Medium capacity public transport is essential on the St Georges Road- Hay Street corridor as far as Leederville, on part of the Beaufort Street corridor and in the Glendalough-Innaloo area. The branch line to QE II and UWA as well as the segments between Leederville and Glendalough via Mount Hawthorn, however, could conceivably also function as bus-based corridors in 2031 unless more ambitious targets for additional urban intensification were pursued there. The link between Morley centre and Embleton interchange continues to be the weakest segment of the proposed Trackless Tram network. Conversely, the Causeway is the only segment that falls in the 'overwhelmed' category even for a medium-capacity





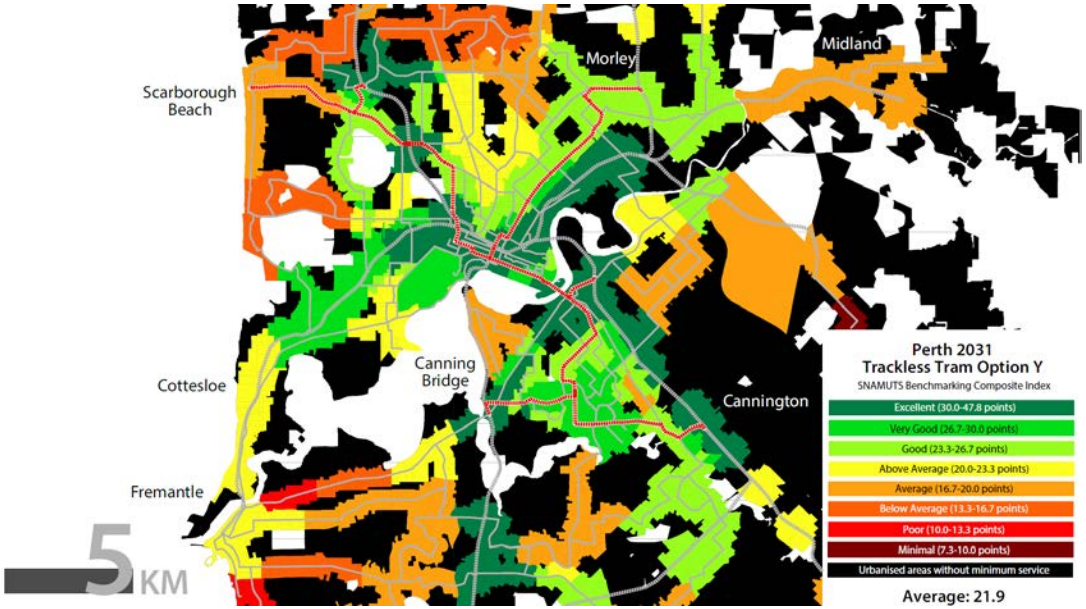
mode. The Trackless Tram project clearly helps to increase the capacity of this link and thus buys time for the planning and implementation of an additional public transport river crossing into the CBD, though in can be expected that the rationale for such a project will gather pace at some stage after 2031.

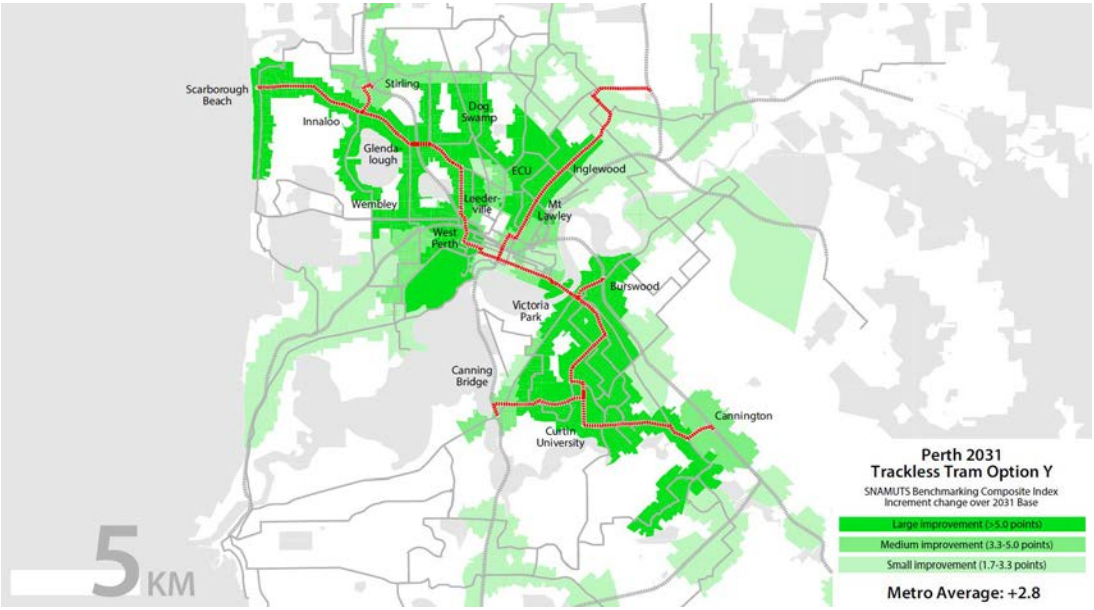
Figures 59-60: *Mode capitalisation diagrams for Trackless Tram Options Y and Z with additional land use intensification*

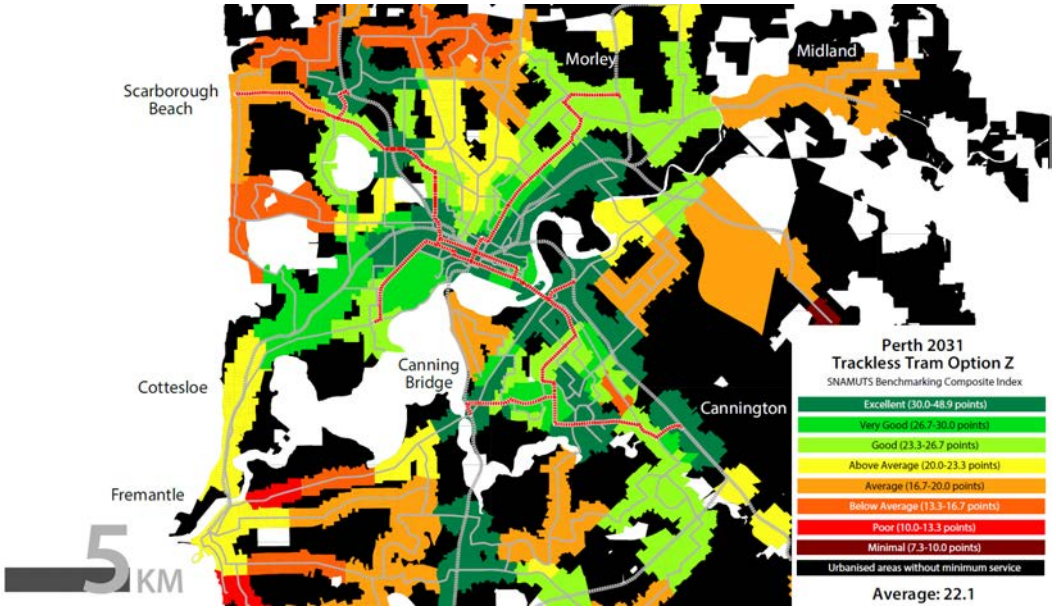
SNAMUTS composite index

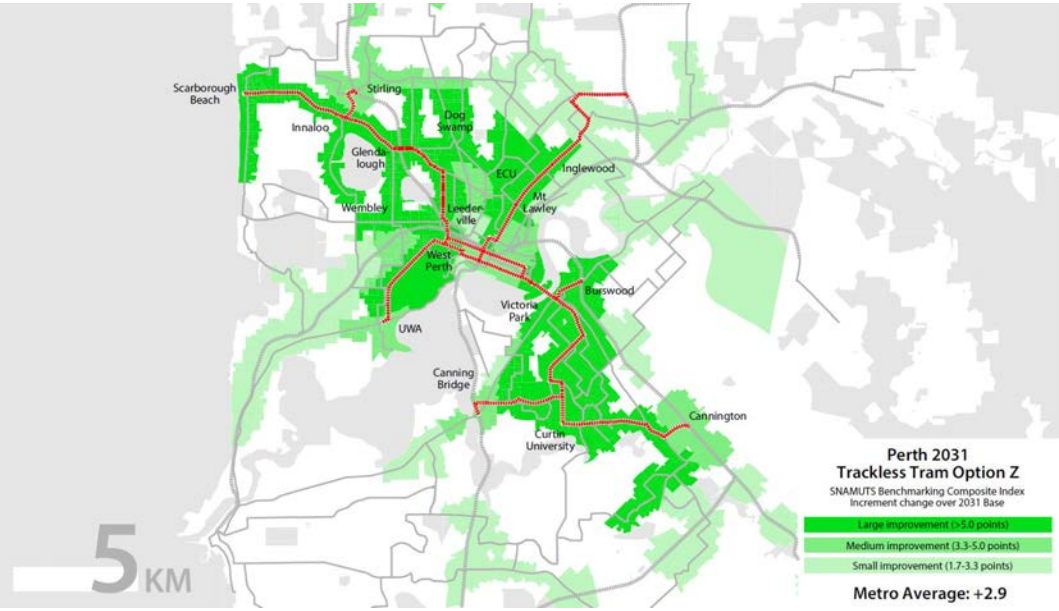
Figures 61-64 show the composite index maps for Trackless Tram Options Y and Z, as well as the incremental change of composite accessibility performance compared to the 2031 network and land use trend (see section 4 for a description of these indexes). Both scenarios place all catchments of Trackless Tram routes, except for the outer end of the Scarborough line, into the good to excellent (green) accessibility categories. With the exception of the South Perth area and (in Option Y) a small gap in North Perth, tangible accessibility improvements to the 2031 Trend extend across practically all of inner Perth, and many areas in the middle suburbs.

Figures 61-64: *SNAMUTS Composite Index and Composite Increment Change for Trackless Tram Options Y and Z with additional land use intensification*






Scarborough Beach
Morley
Midland
Cottesloe
Canning Bridge
Cannington
Fremantle
5 KM
Perth 2031
Trackless Tram Option Z
SNAMUTS Benchmarking Composite Index
Excellent (30.0-48.9 points)
Very Good (26.7-30.0 points)
Good (23.3-26.7 points)
Above Average (20.0-23.3 points)
Average (16.7-20.0 points)
Below Average (13.3-16.7 points)
Poor (10.0-13.3 points)
Minimal (7.3-10.0 points)
Urbanised areas without minimum service
Average: 22.1


Scarborough Beach
Stirling
Innaloo
Dog swamp
Glendalough
ECU
Inglewood
Wembley
Leederville
Mt Lawley
West Perth
Burswood
Victoria Park
UWA
Canning Bridge
Cannington
Curtin University
5 KM
Perth 2031
Trackless Tram Option Z
SNAMUTS Benchmarking Composite Index
Increment change over 2031 Base
Large improvement (>5.0 points)
Medium improvement (3.3-5.0 points)
Small improvement (1.7-3.3 points)
Metro Average: +2.9

Summary and Recommendations

Trackless Tram/Medium Capacity Transit rationale

Perth's public transport system is characterised by a widening performance and capacity gap between the two principal modes currently in use: rail and buses.

A plethora of radial bus lines enter the CBD area along a small number of trunk routes, in a pattern that originated at a time when the metropolitan population was far smaller than today. As Perth has begun to attract its third million of residents, this pattern has reached its performance and capacity limit particularly along the St Georges Terrace, Adelaide Terrace and Causeway corridor.

Urban growth increases pressure for the decentralisation of knowledge-based employment and associated residential and service functions into higher-density growth hubs in middle suburbs and around universities, such as Stirling, Cannington and Bentley. Linking these growth hubs to each other and to the heavy rail network requires a second-tier transport system with greater performance and capacity than conventional buses.

Scenario Analysis

A staged strategy for the replacement of the CBD bus trunk routes by a medium-capacity transit mode such as the Trackless Tram forms the most critical part of any transformation of Perth's public transport network into a three-tiered system (rail, medium-capacity transit, bus).

The SNAMUTS scenario analysis has shown that a full public transport reservation along St Georges/Adelaide Terrace and the Causeway with optimised priority at intersections is a superior alignment choice over alternatives such as Terrace Road/Riverside Drive. In the medium term, a second alignment of a similar standard along Wellington Street will also be of benefit.

Linking the CBD Trackless Tram route directly into CBD fringe rail stations (Leederville, City West, Burswood) will generate a range of attractive new transfer trip relations between the suburban rail corridors and a variety of destinations in the CBD and West Perth; simultaneously, the 'super-hub' at Perth Central station will experience some relief from potential public transport congestion.

To support a Trackless Tram or other medium-capacity mode over the alternative of an improved bus system along the north-western and south-eastern suburban corridors, a dedicated land use intensification strategy over and above currently identified urban growth trends in the affected areas is required. This is particularly true for the Glendalough-Stirling, Bentley-Curtin University and Carousel-Cannington precincts.

To improve network connectivity in these areas and provide further attractive public transport travel options, Trackless Tram branch lines into Stirling and Canning Bridge stations should also be included in a medium-term network vision.

A north-eastern Trackless Tram corridor will require significant urban intensification in the Morley-Embleton area to be viable along its full length from the CBD; however, this has not been investigated in detail in this report.

It is advisable in accessibility terms to redeploy vehicles from the converted CBD bus corridors to new and improved inner suburban orbital bus lines that can act as feeder and distributor routes to the radial Trackless Tram corridors and create a more multi-directional public transport network in these areas.

The conversion of the south-eastern CBD approach from bus to Trackless Tram will delay the point in time when the Causeway reaches its maximum capacity as a public transport corridor. However, it can be expected that as Perth continues to grow both inwardly and outwardly, the need for an additional public transport river crossing will not disappear but can be addressed with considerably less urgency after 2031.

trackless trams in perth
snamuts analysis

Dr Jan Scheurer, RMIT University/Curtin University

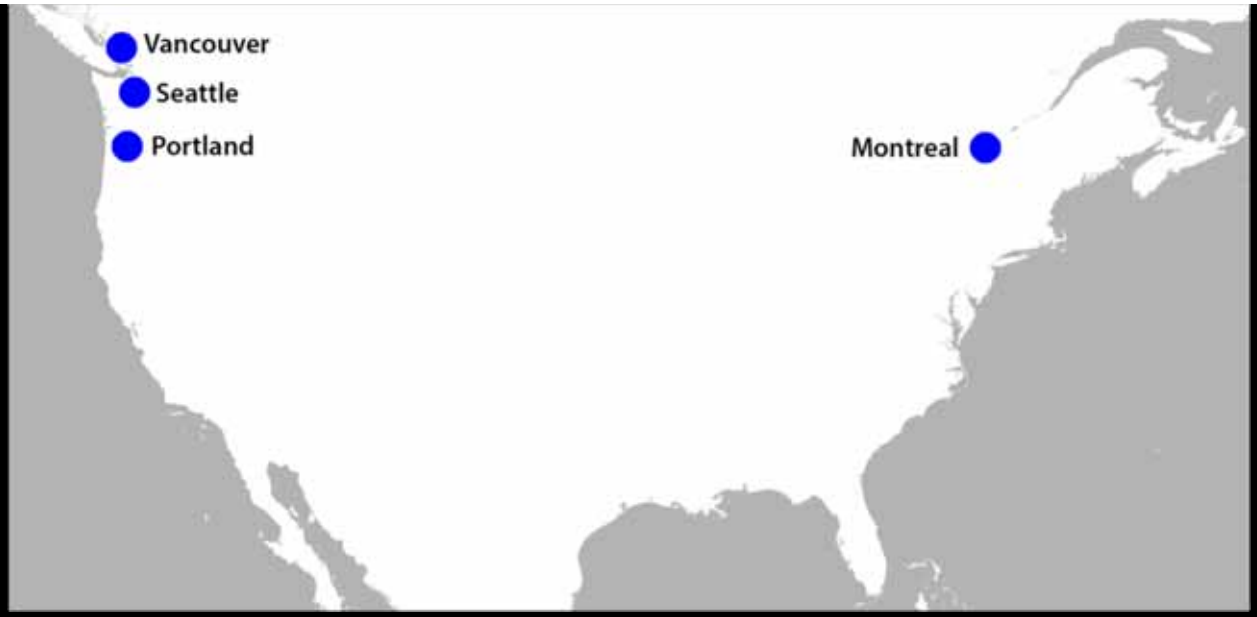
Source: MacroPlanDimasi

spatial network analysis for multimodal urban transport systems (snamuts)

SNAMUTS is a GIS-based analytic tool for public transport network performance, spatial accessibility and integrated land use-transport planning.

It is inspired by the Space Syntax and Multiple Centrality Assessment methodologies and takes a **supply-side, discursive, network-wide perspective** on trans-disciplinary decision-making tasks:

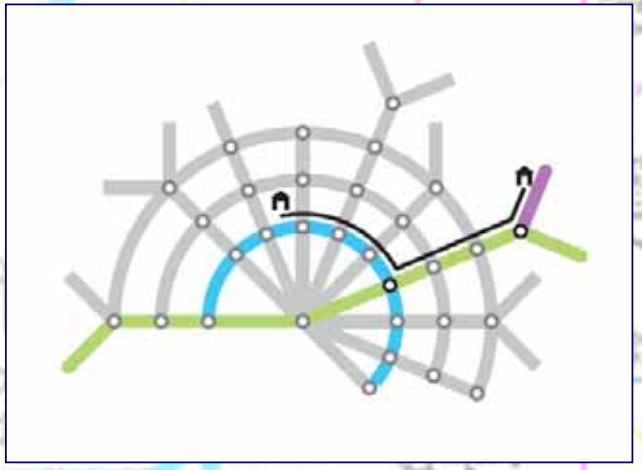
What is the role of the public transport system in facilitating movement and activity across a city region?



snamuts global

+ Singapore
+ Hong Kong
+ Göteborg
+ Helsinki
+ Stockholm
+ Oslo
+ Zuid Holland
+ Utrecht

‘the network effect’



The performance of a network can be improved through locally optimised routes, good interchange facilities, high and standardised service frequencies, timetable coordination and the presence of routes in different directions (radial, orbital, diagonal).

Map Sources: www.railpage.com.au, www.hitrans.org

how can snamuts help us make better policy decisions?

Network Effect: The utility of a public transport network is greater than the sum of its parts!

Interplay of Land Use and Transport: How does urban growth translate into added pressure on public transport, and where does it provide new opportunities for movement?

Latent Demand: Identifying public transport market potential in areas where it is currently marginal, and assessing infrastructure and service proposals for their ability to mobilise it

public transport from the user perspective

public transport in central perth:
where are we at?

Perth's CBD is becoming saturated with buses.

Finite capacity per vehicle and the limitations of available road and terminal space place constraints to the future expansion and reliable operations of services.

Source: YouTube

Source: WA Today

Source: West Australian

Source: West Australian

Perth's urban growth rate remains high.

This leads to spatial expansion, urban intensification, increased demand on infrastructure and mounting congestion on both road and public transport systems.

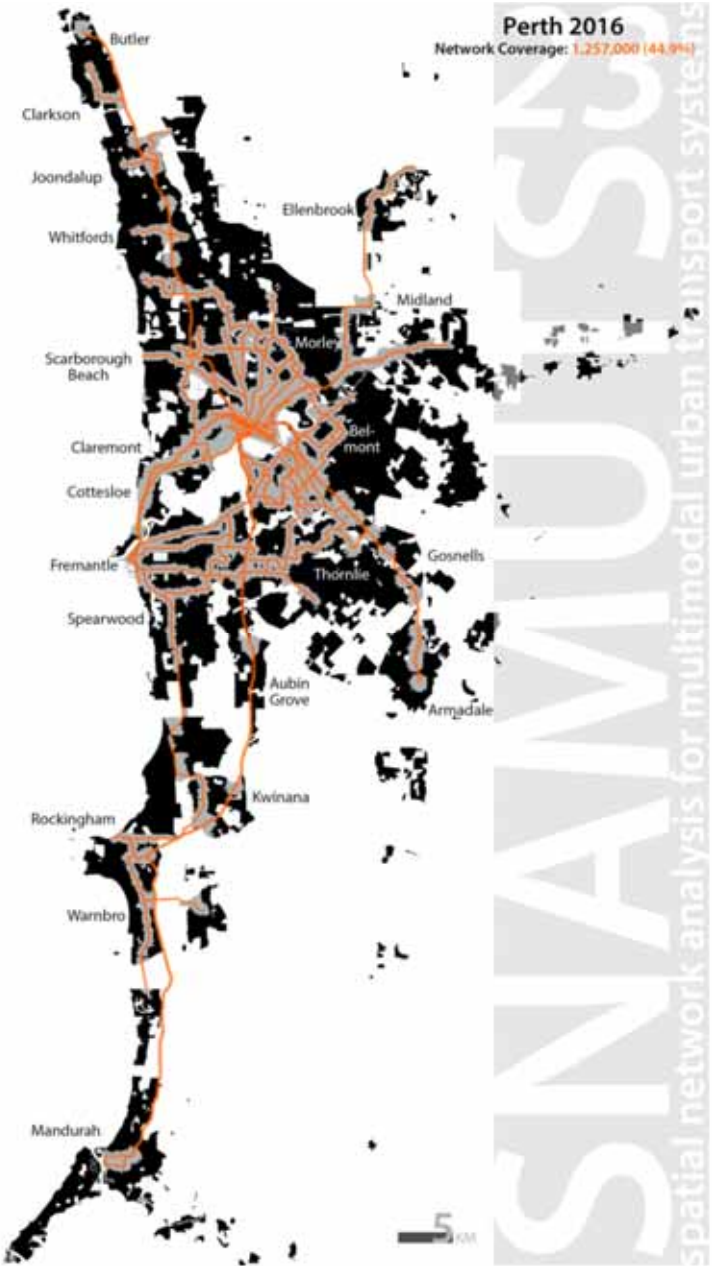
Source: Western Independent

But Perth does not yet experience the magnitude of adverse effects in other, larger Australian cities.

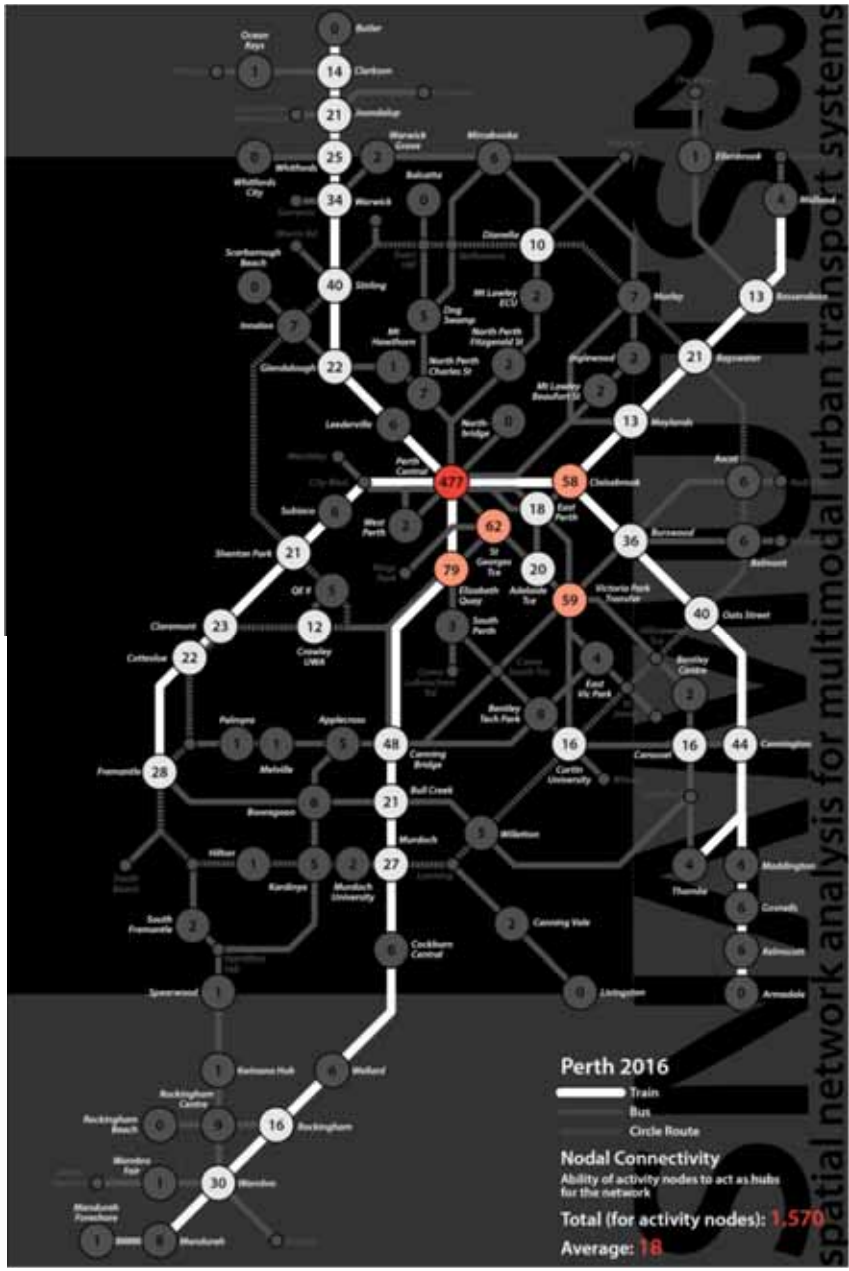
A continuing pipeline of public transport expansion and improvements can future-proof our city against this predicament.

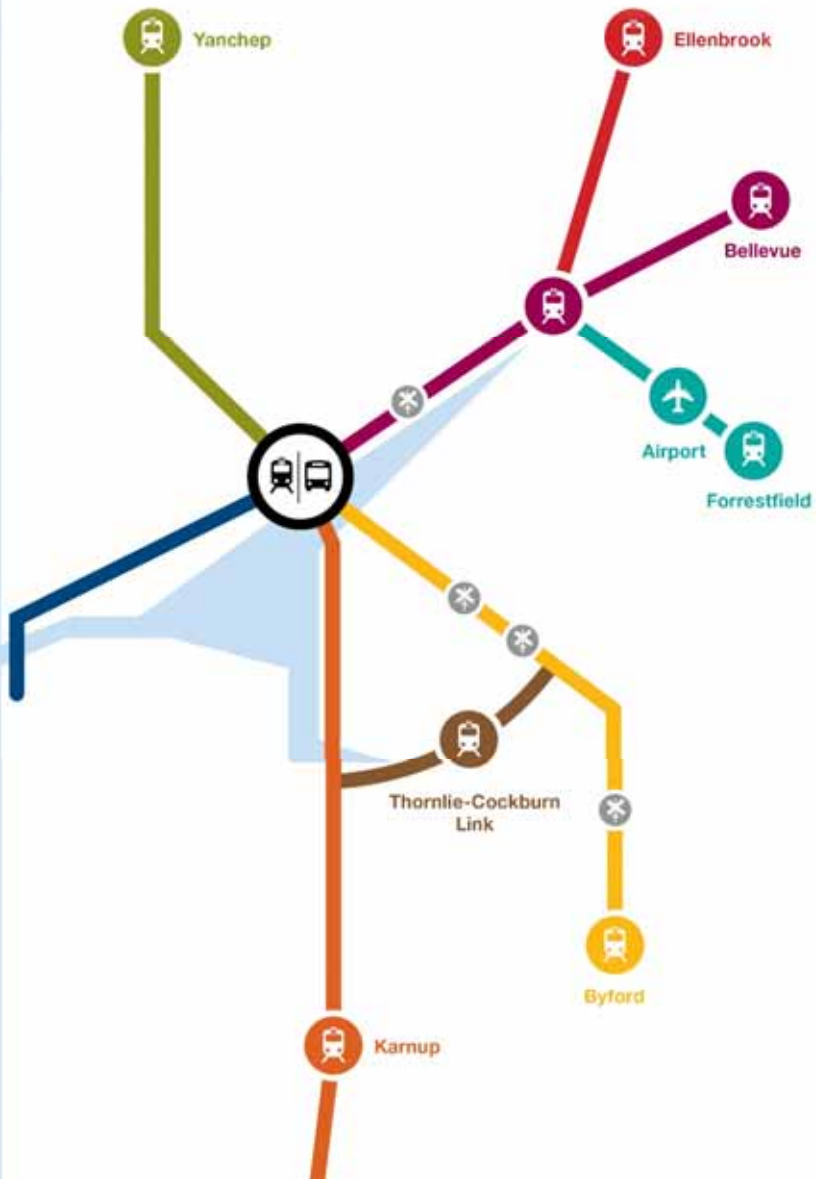
Source: Lifehacker Australia

Source: ABC



However, compared to many international cities Perth's public transport has severe shortcomings. Overcoming these is critical if public transport were to become a more widespread travel choice.





Metronet is a package of measures to significantly expand and improve the performance of Perth's rail system.

However, the measures are focused on the middle and outer suburbs. On their own, they will add to rather than relieve Perth's inner area from pressure.

What operational speeds can be achieved by Trackless Trams?
Travel time assumptions...

Gold Coast Light Rail (Stage 1 opened 2014, stage 2 2017)
Average speed, Stage 1: 23.6 km/h, Stage 1+2: 27.1 km/h

Capital Metro, Canberra (opens 2018)
Estimated average speed: 30 km/h

Melbourne:
Average tram speed 16 km/h (11 km/h in the CBD)

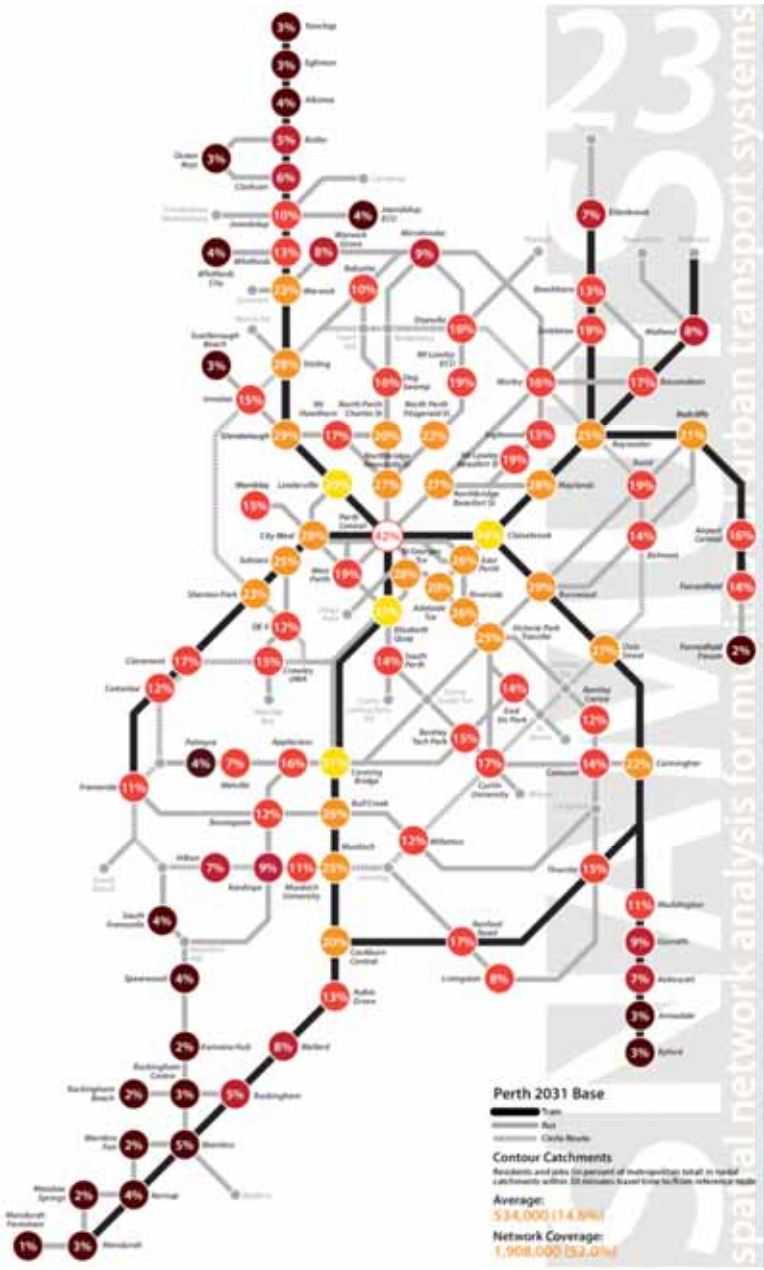
Assumptions for Perth:
20 km/h environments (eg. Hay Street, Albany Highway)

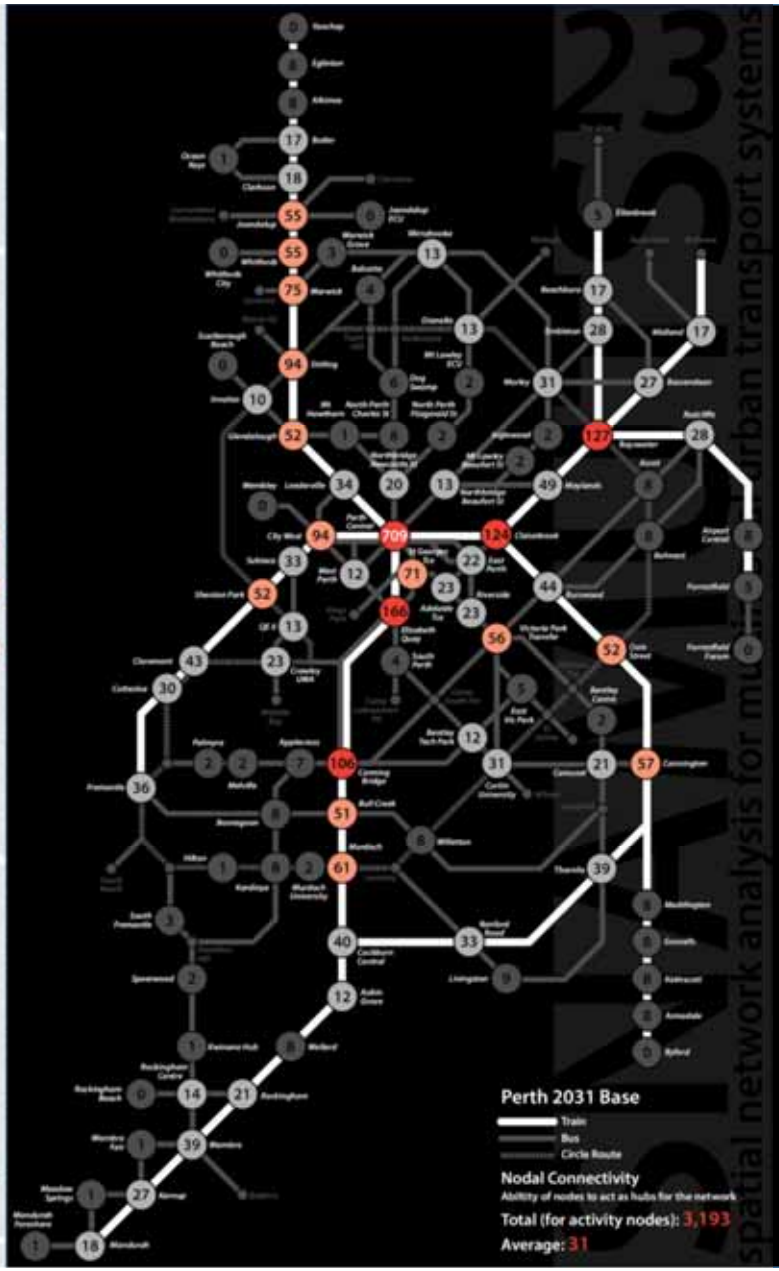
Assumptions for Perth:
25 km/h environments (eg. Kent Street, St Georges Terrace)

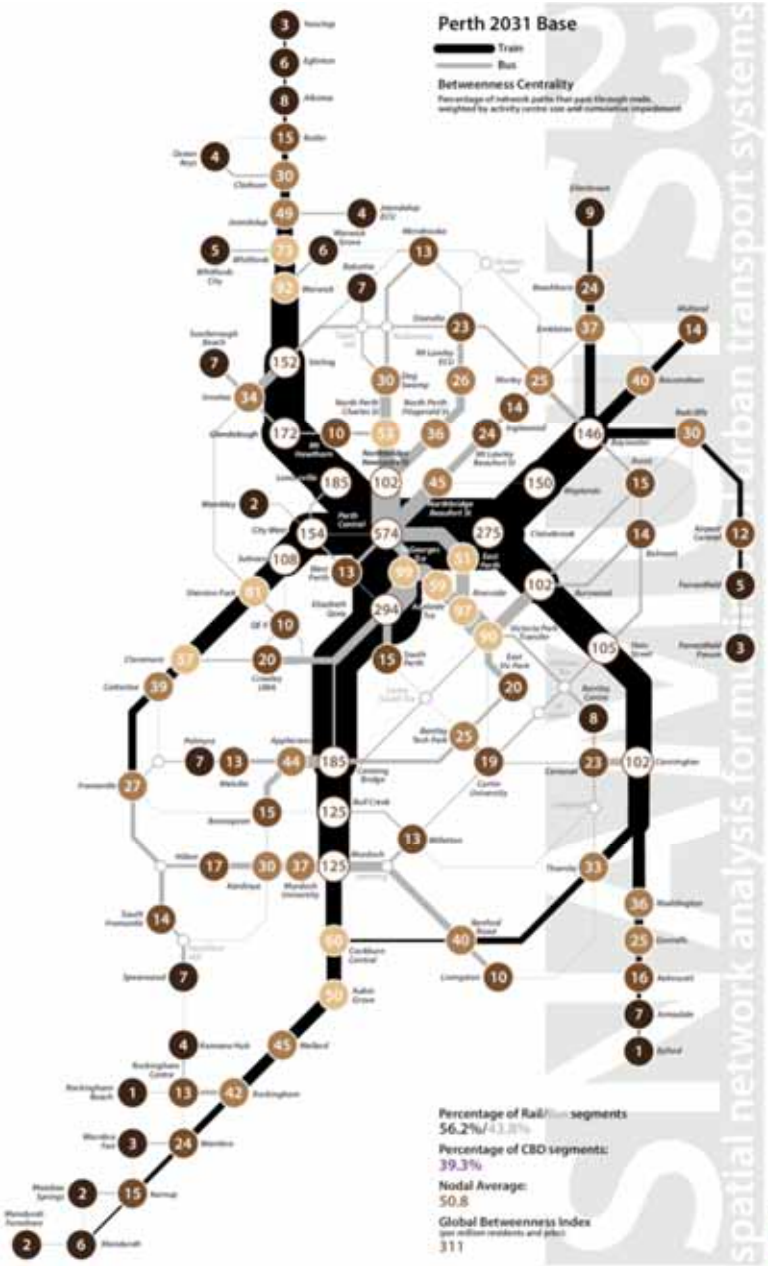
Assumptions for Perth:
30 km/h environments (eg. Jackson Road, Winthrop Avenue)

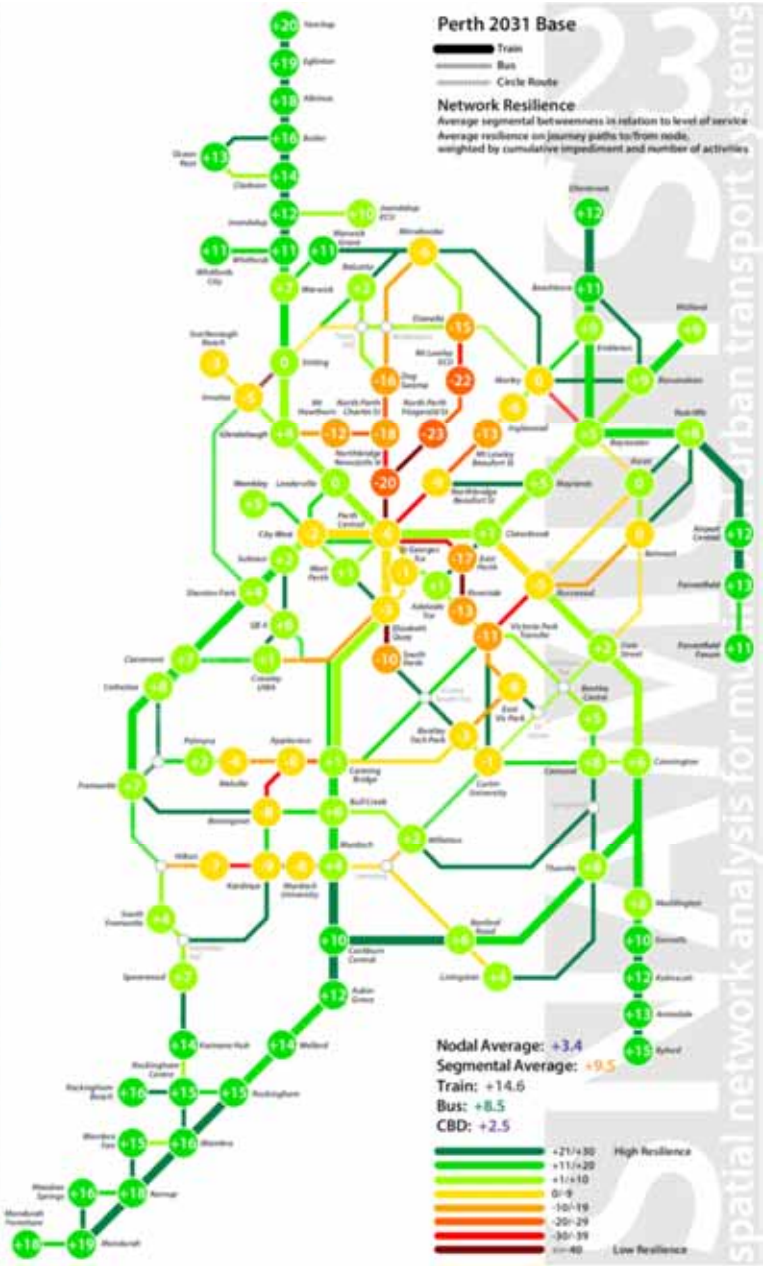
perth’s public transport in 2031...

2031 base


Perth 2031 Base
Train
Bus
Circle Route
Contour Catchments
Average:
534,000 (14.9%)
Network Coverage:
1,908,000 (52.0%)

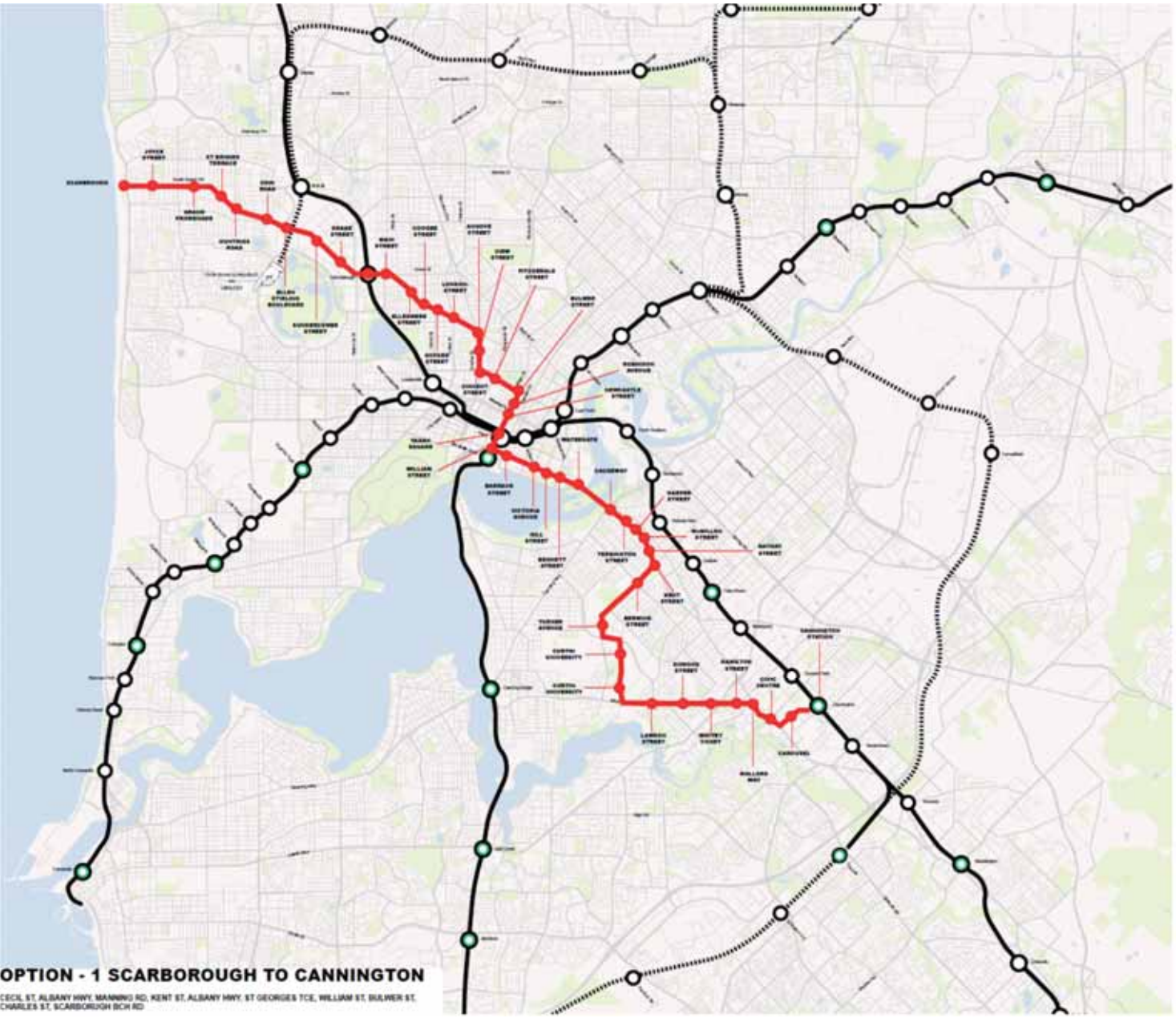

Perth 2031 Base
Train
Bus
Circle Route
Nodal Connectivity
Ability of nodes to act as hubs for the network
Total (for activity nodes): 3,193
Average: 31


Perth 2031 Base
Train
Bus
Betweenness Centrality
Percentage of CBD segments:
39.3%
Nodal Average:
50.8
Global Betweenness Index
311


Perth 2031 Base
Train
Bus
Circle Route
Network Resilience
Nodal Average: +3.4
Segmental Average: +9.5
Train: +14.6
Bus: +8.5
CBD: +2.5
High Resilience
Low Resilience

2031 base

trackless trams for perth:
three route scenarios
(scarborough beach to cannington)

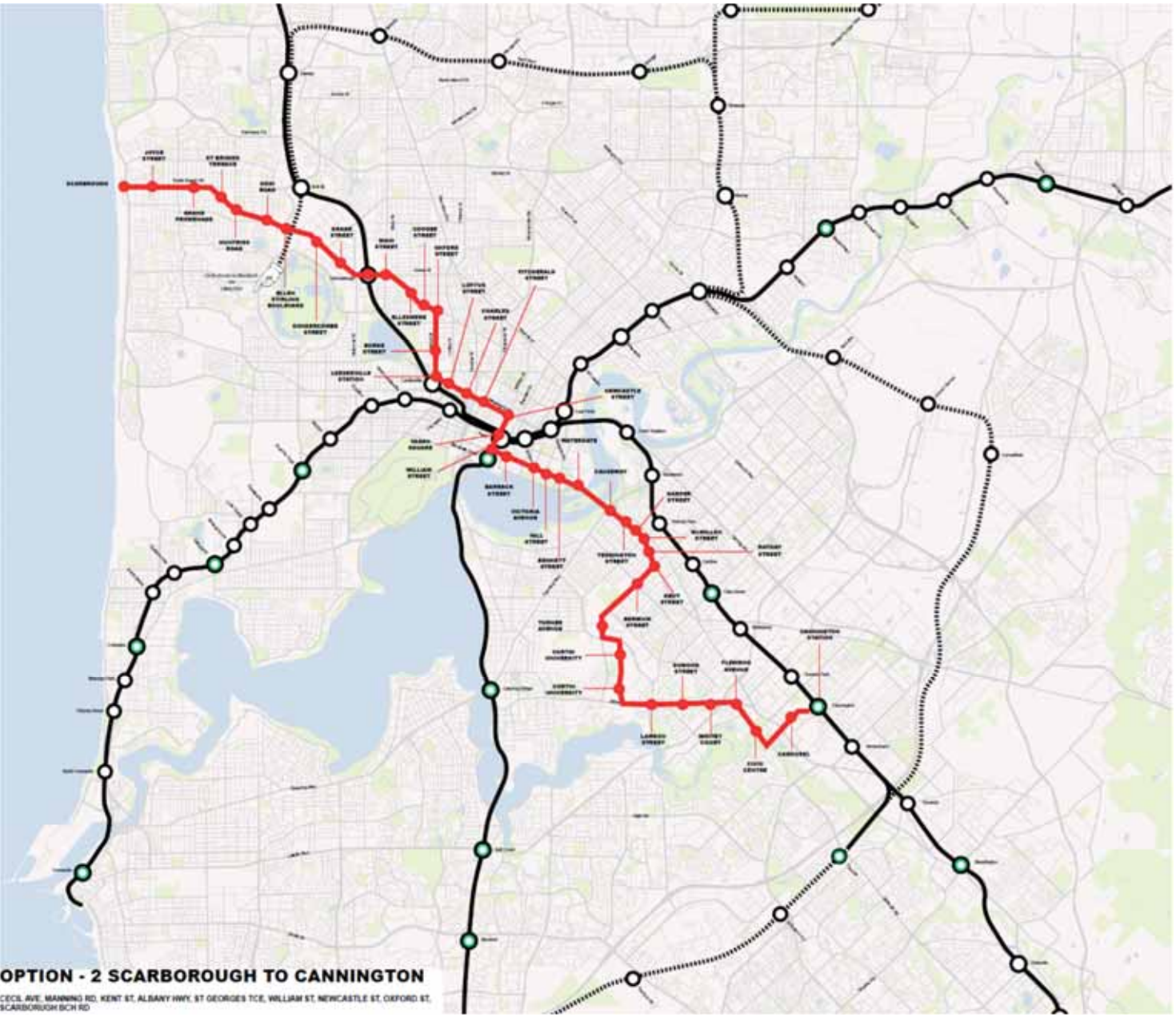


Trackless Tram Option 1

Replaces bus routes 34 and 100 (east of Curtin Uni), 960 (south), 990

St Georges Terrace and Adelaide Terrace buses are rerouted via Wellington St and Riverside Drive.

Requires 22 Trackless Tram vehicles in simultaneous operation and frees 6 buses for redeployment on two new inner orbital routes to support the Trackless Tram.

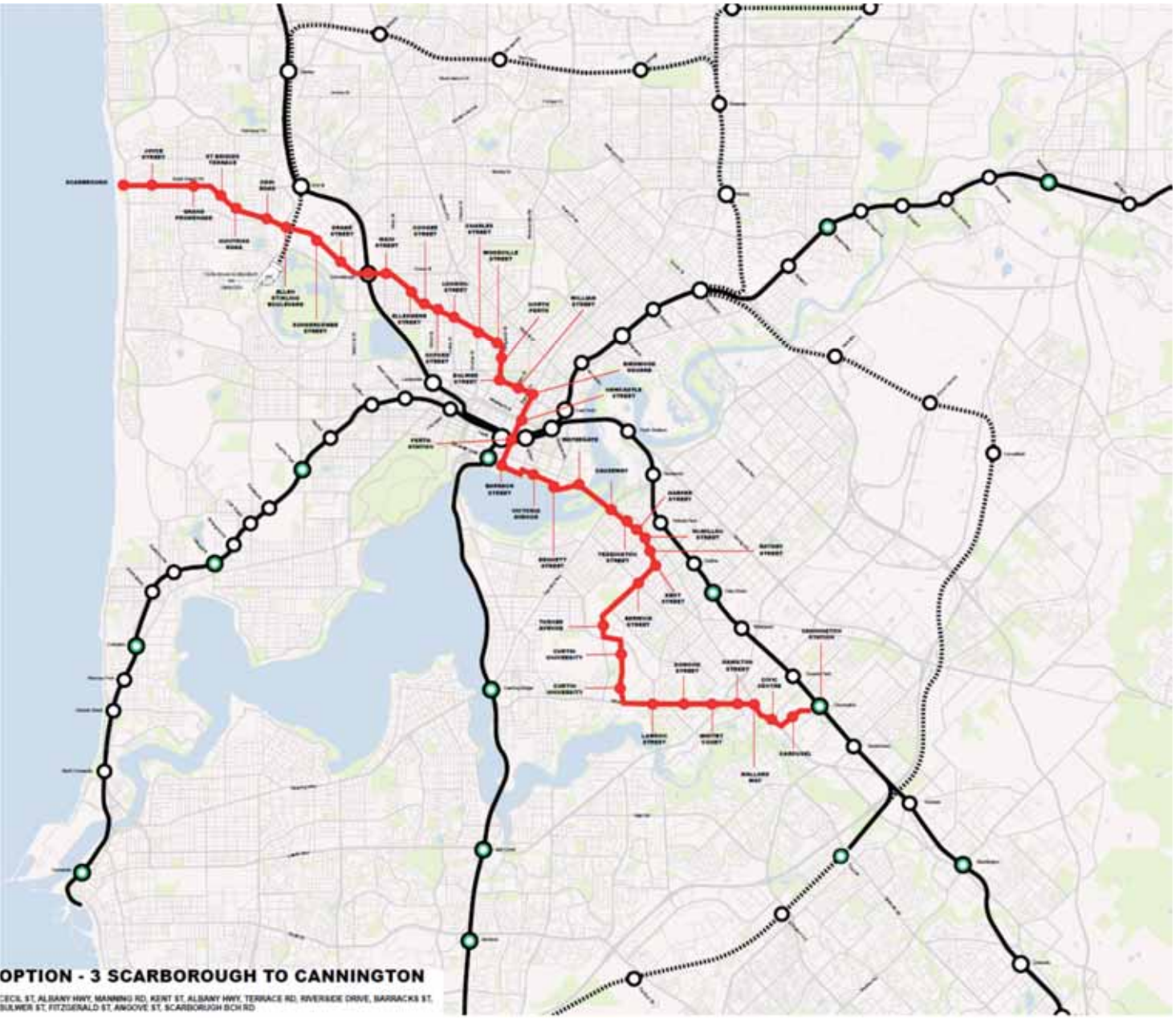


Trackless Tram Option 2

Replaces bus routes 34 and 100 (east of Curtin Uni), 960 (south), 990

St Georges Terrace and Adelaide Terrace buses are rerouted via Wellington St and Riverside Drive.

Requires 22 Trackless Tram vehicles in simultaneous operation and frees 6 buses for redeployment on two new inner orbital routes to support the Trackless Tram.



Trackless Tram Option 3

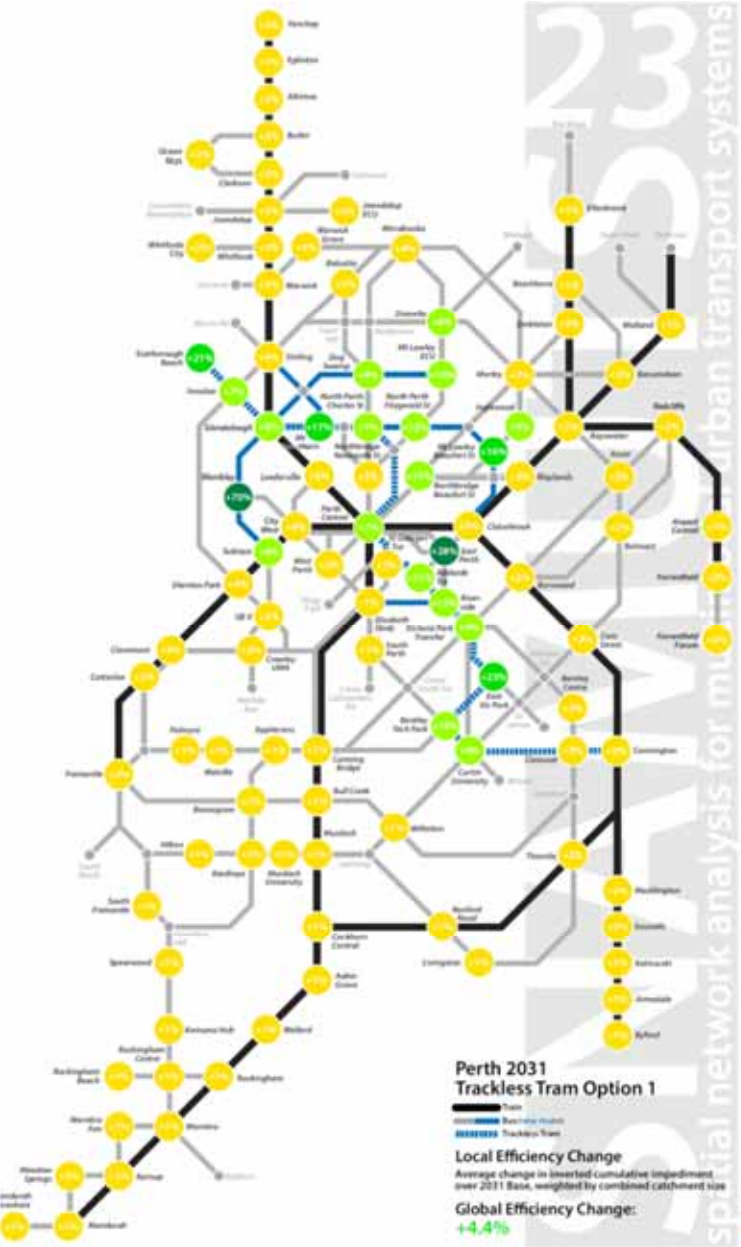
Replaces bus routes 34 and 100 (east of Curtin Uni), 960 (south), 990

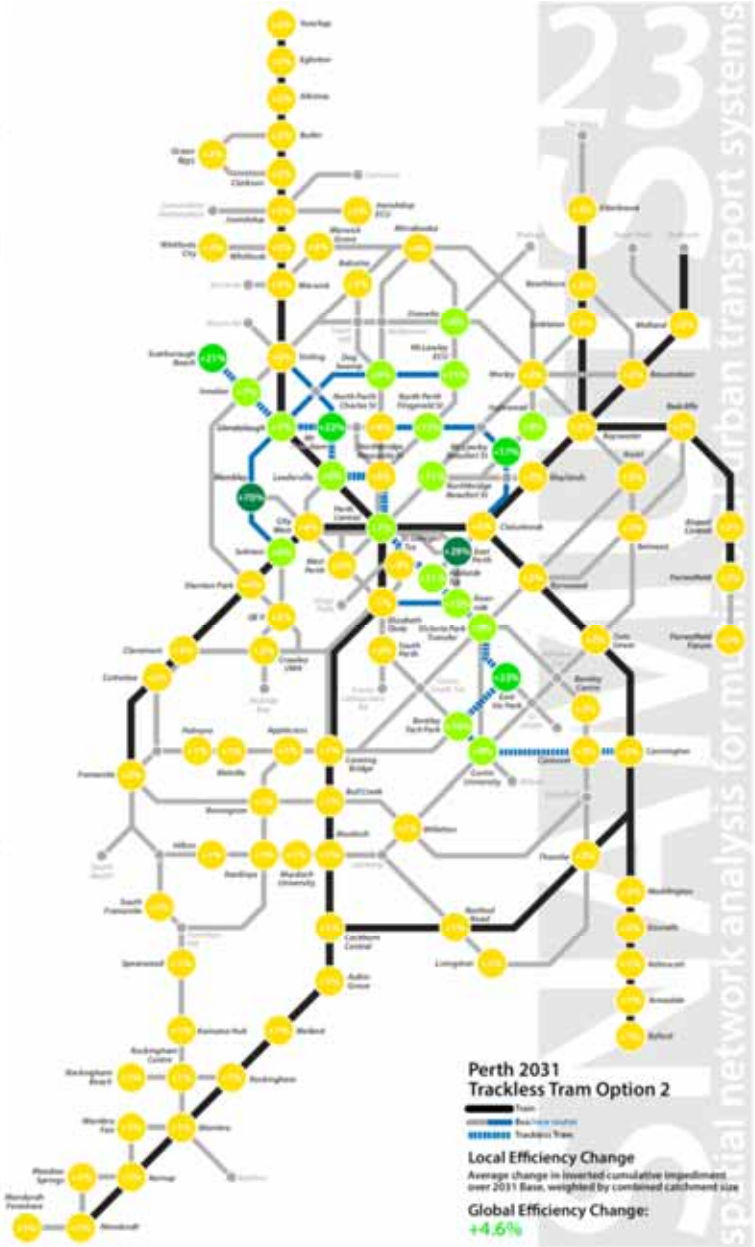
Other CBD buses remain unchanged

Requires 20 Trackless Tram vehicles in simultaneous operation, but frees no additional buses for redeployment.

efficiency change:

by how much does the proposed line improve the public transport-land use system across metropolitan perth and at each location?


Perth 2031
Trackless Tram Option 1
Train
Bus
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2011 Base, weighted by combined catchment size
Global Efficiency Change:
+4.4%

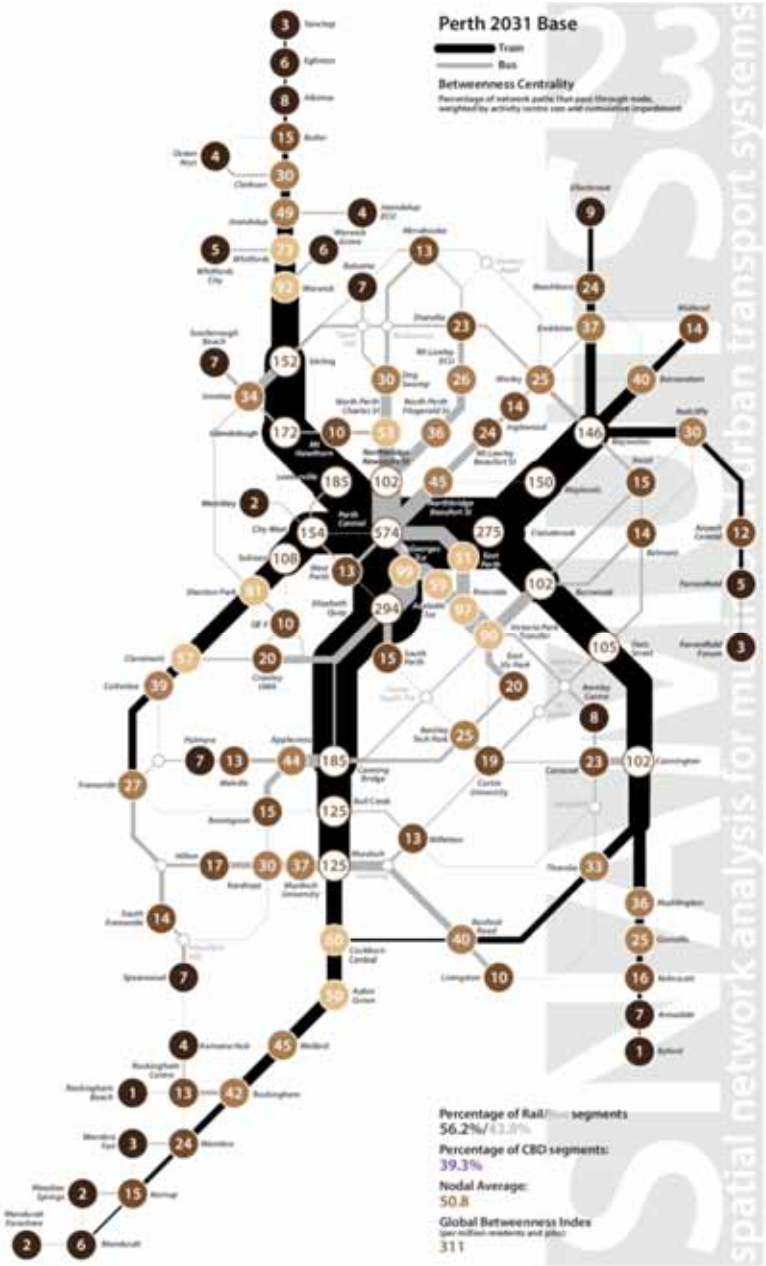

Perth 2031
Trackless Tram Option 2
Train
Bus
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2011 Base, weighted by combined catchment size
Global Efficiency Change:
+4.6%

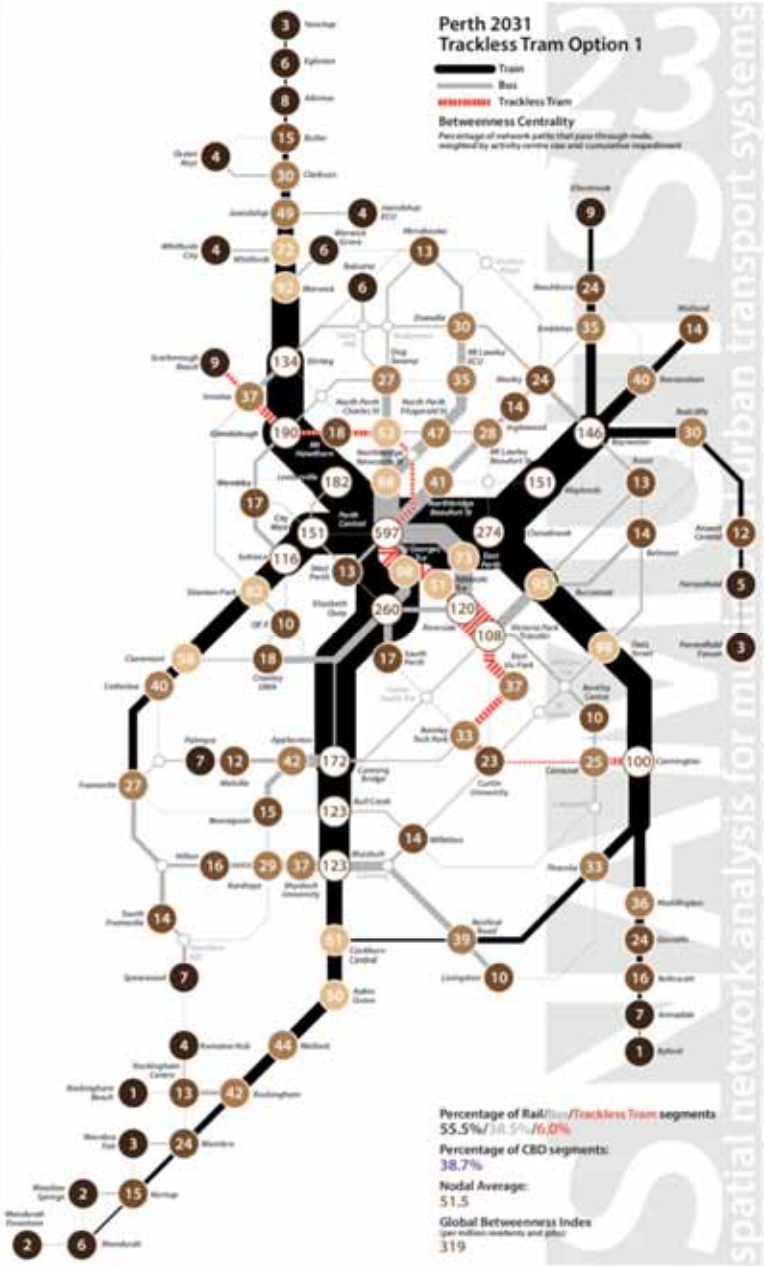

Perth 2031
Trackless Tram Option 3
Train
Bus
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2011 Base, weighted by combined catchment size
Global Efficiency Change:
+1.9%

betweenness centrality:

where does the trackless tram system add travel opportunities in perth?

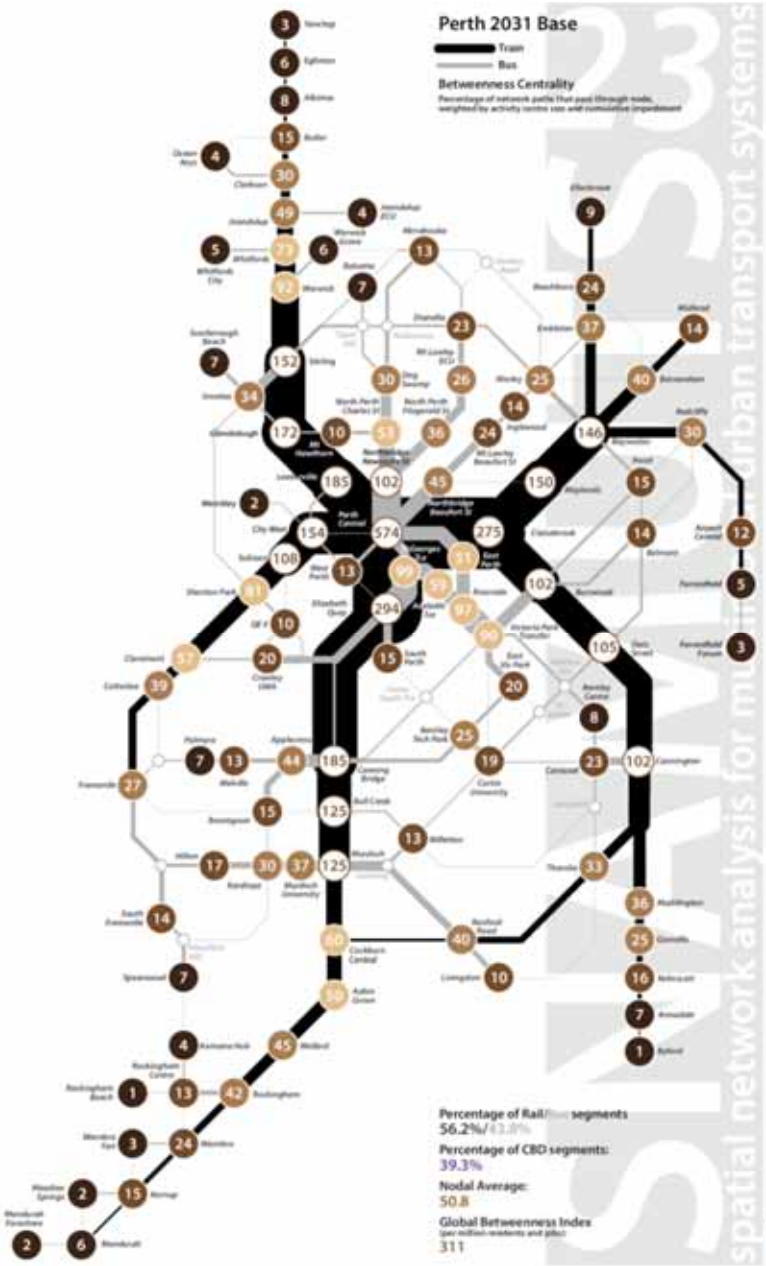
2031 base

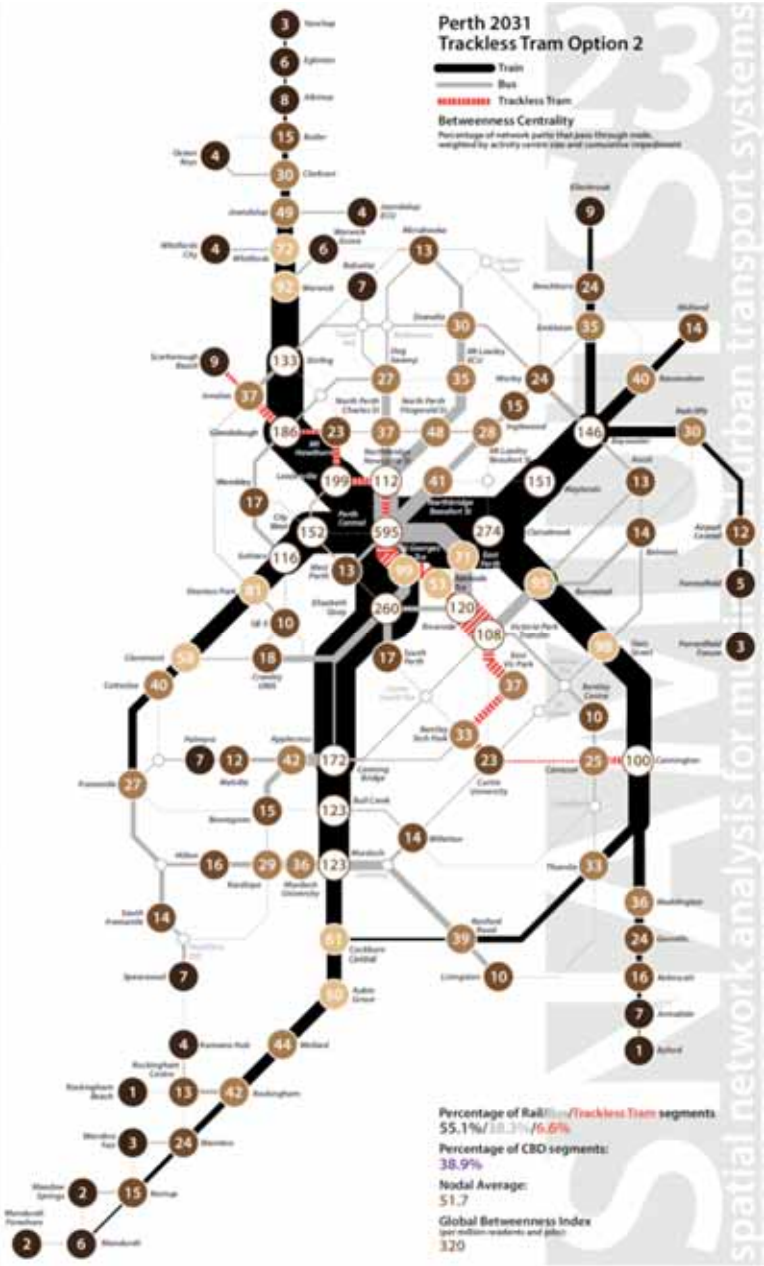




option 1

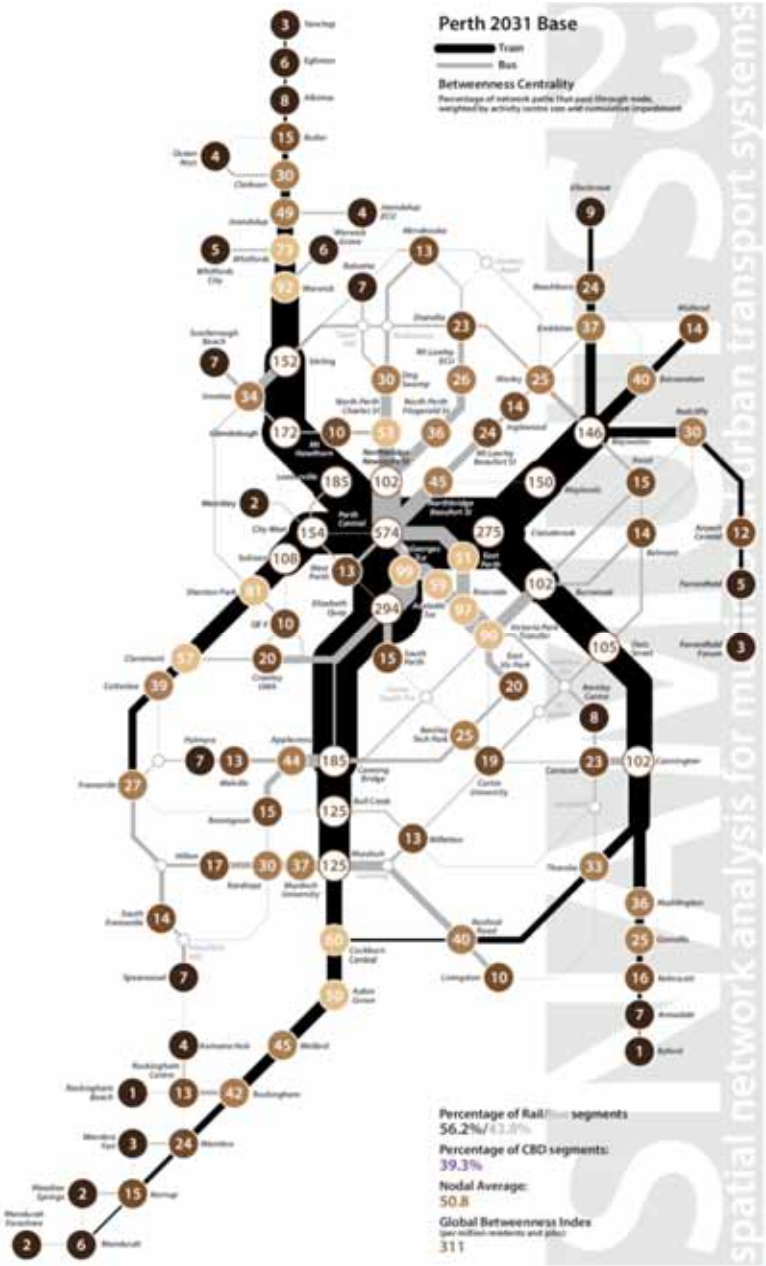
2031 base

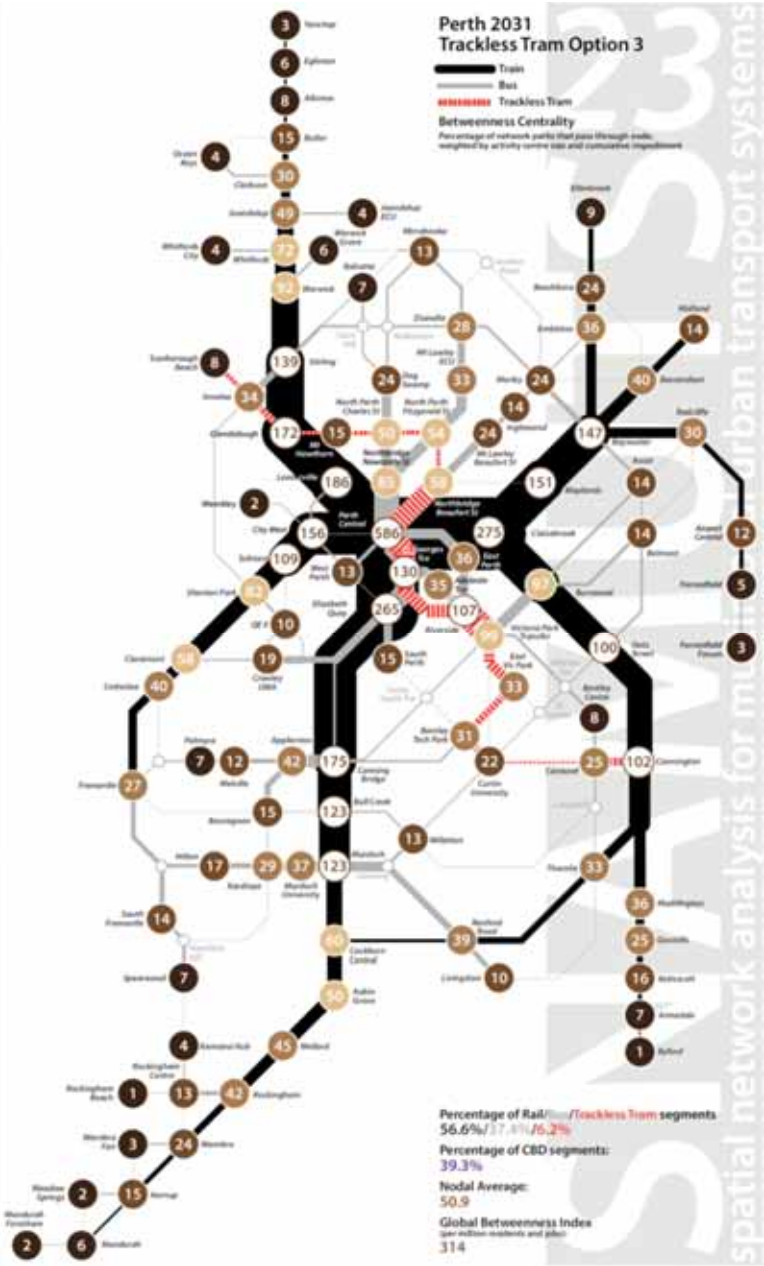




option 2

2031 base



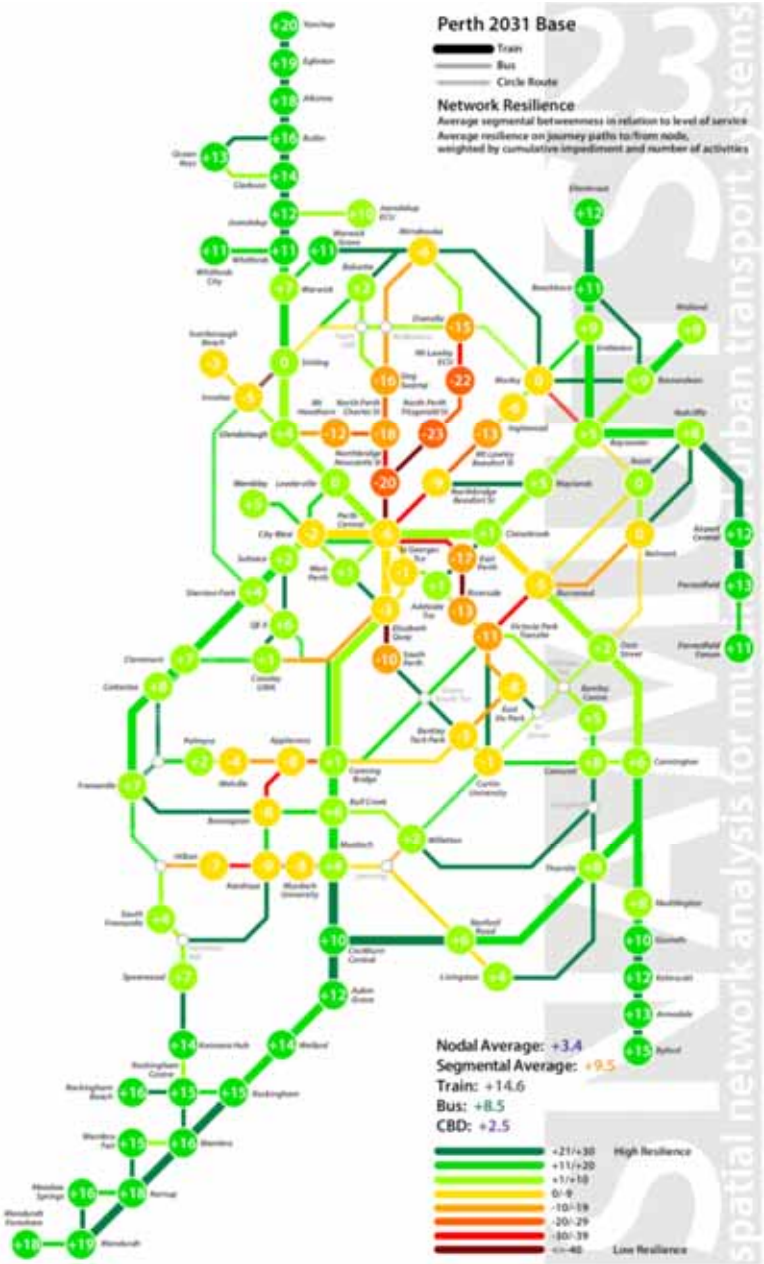


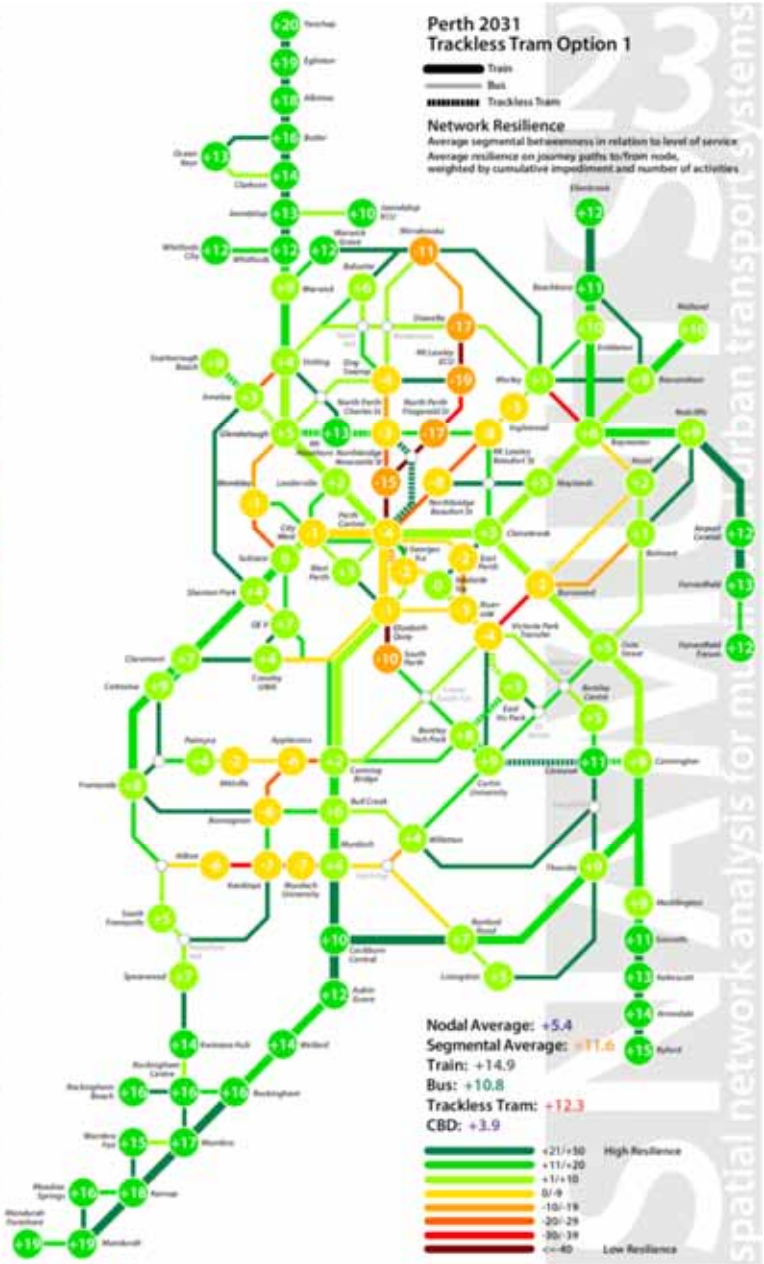
option 3

network resilence:

are the travel opportunities well-catered for by public transport capacity? where can we see problems?

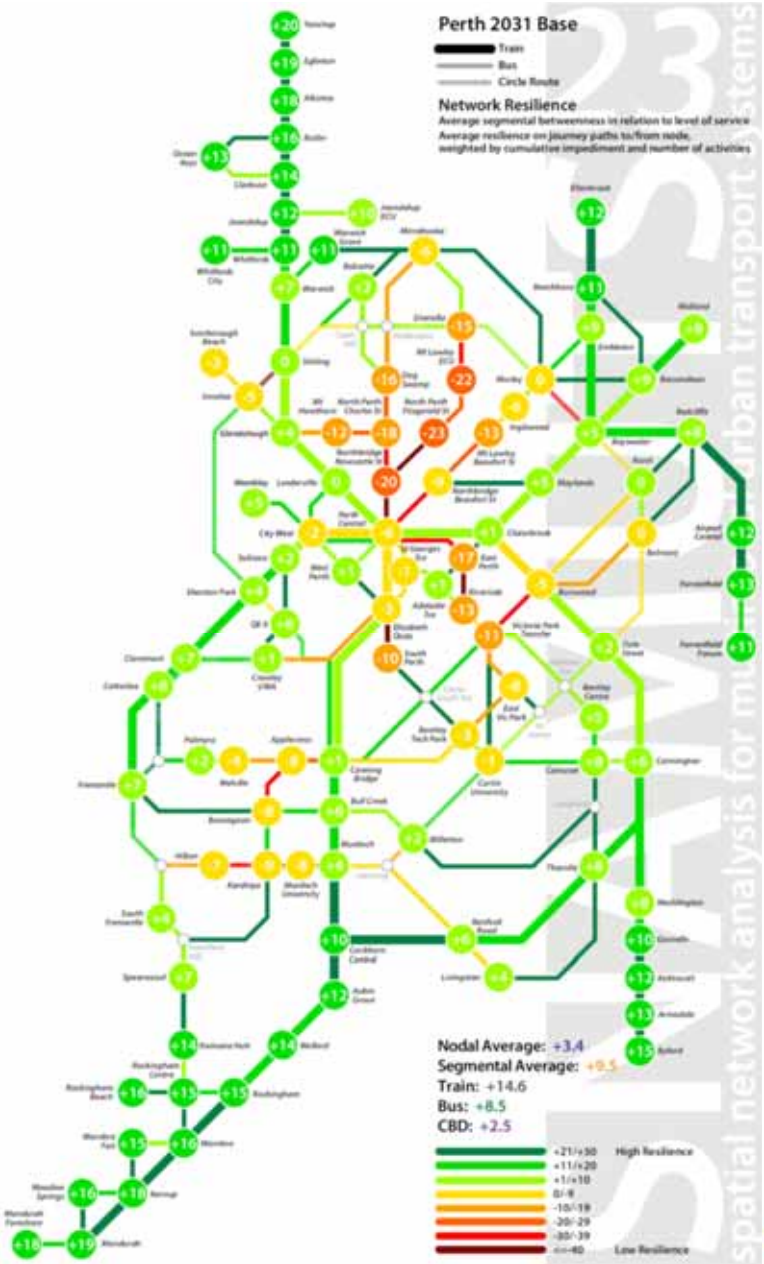
2031 base

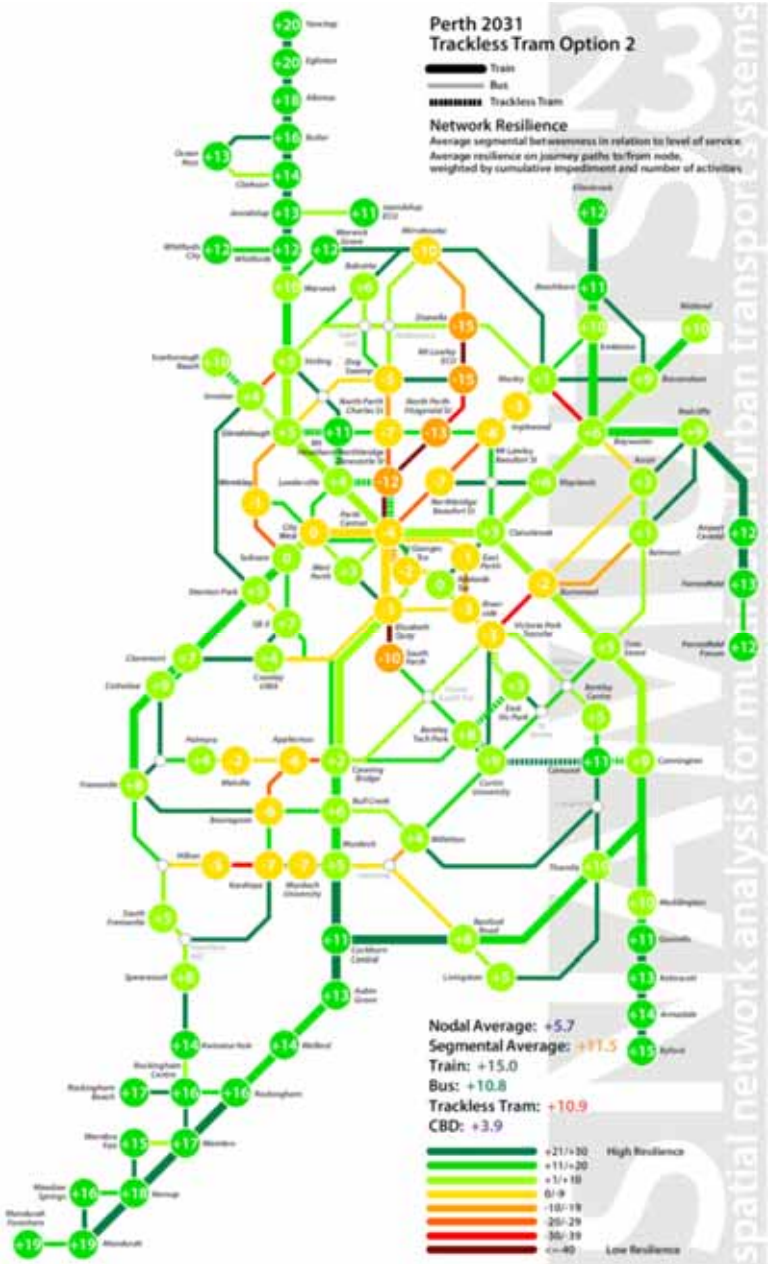




option 1

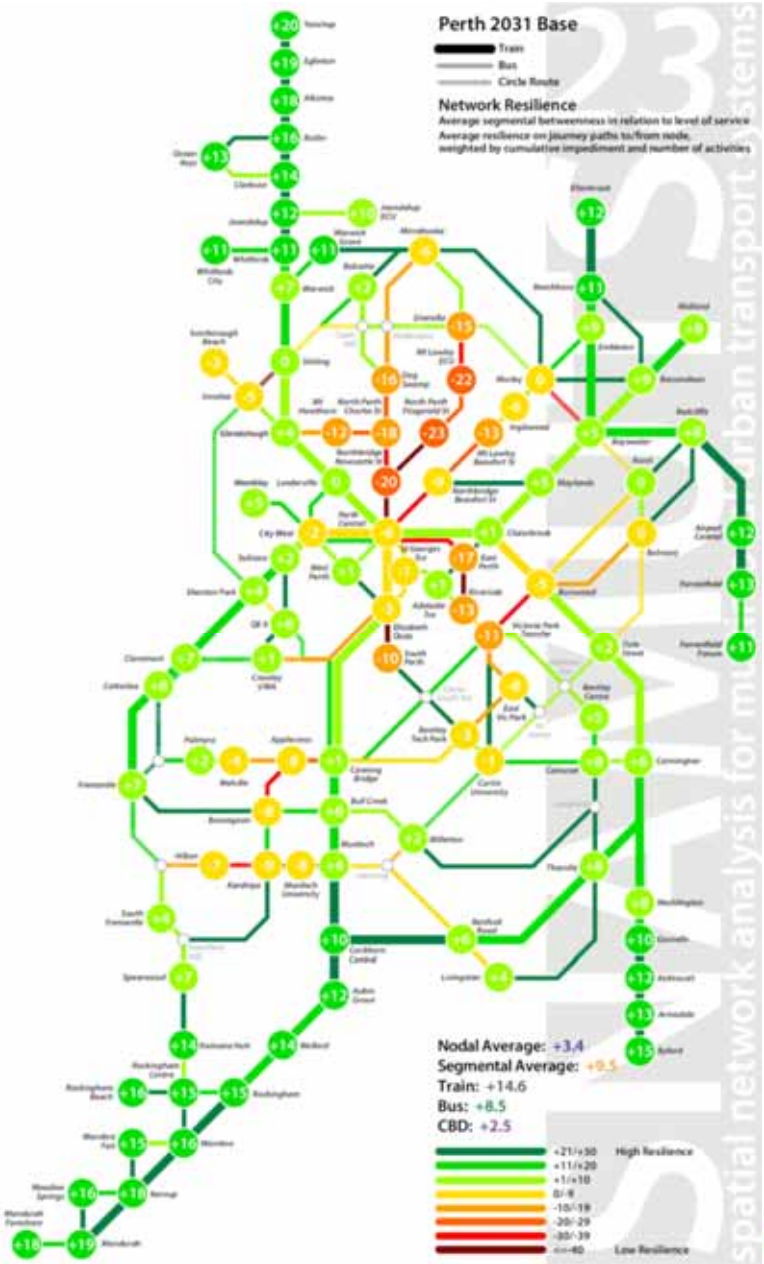
2031 base

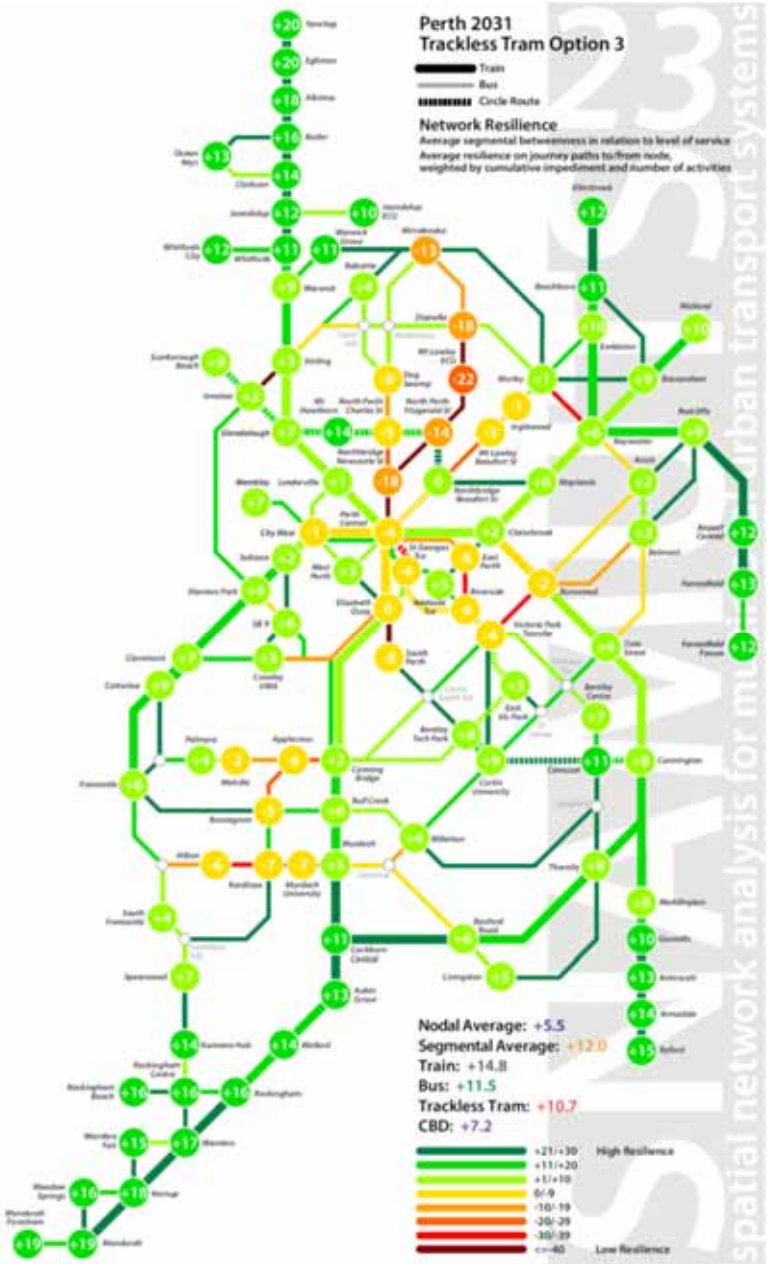




option 2

2031 base

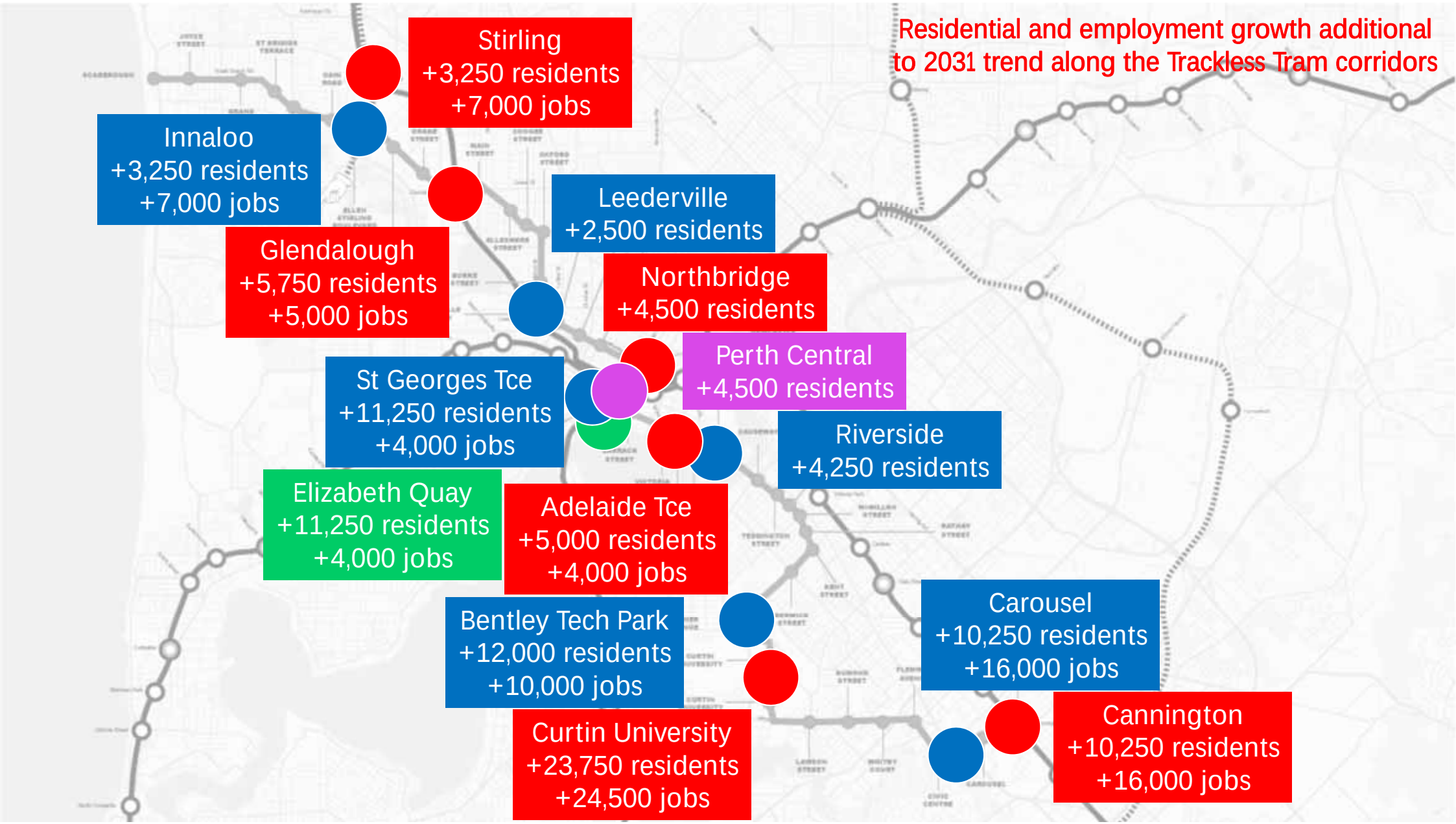


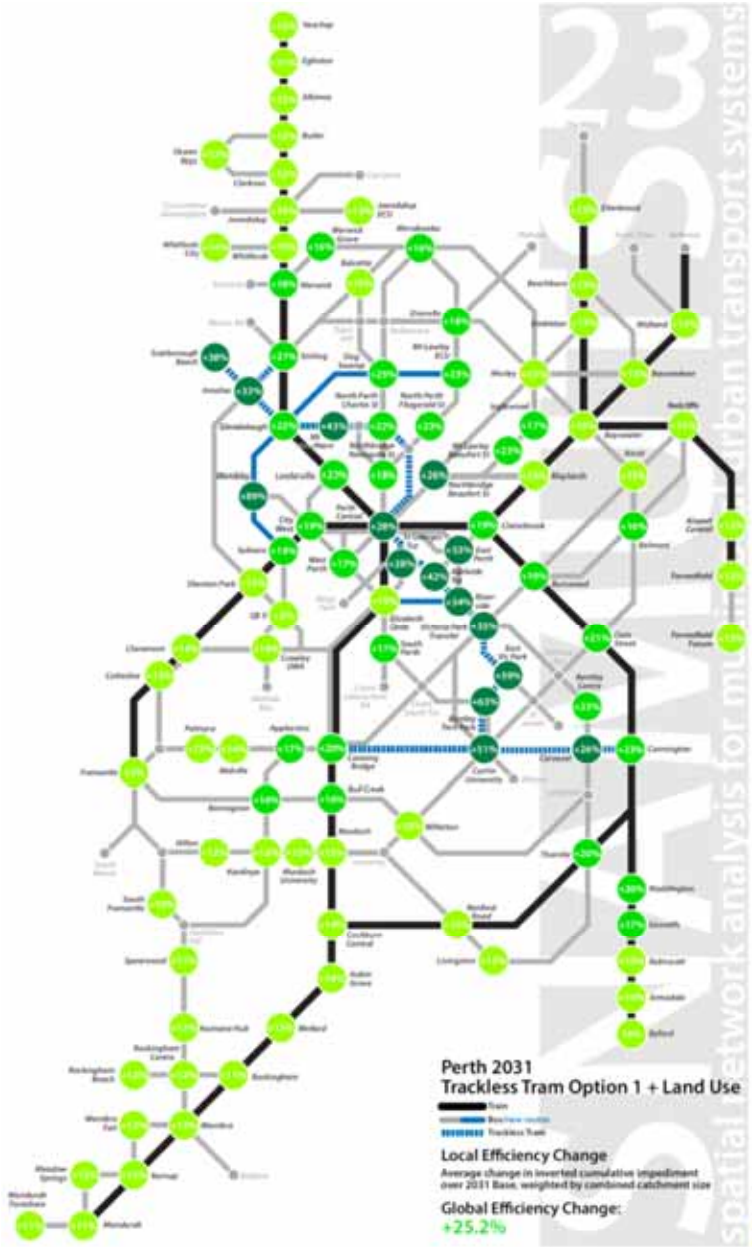


option 3

urban intensification:

along the trackless tram routes, where can we identify potential for residential and employment growth over and beyond the trend for 2031?

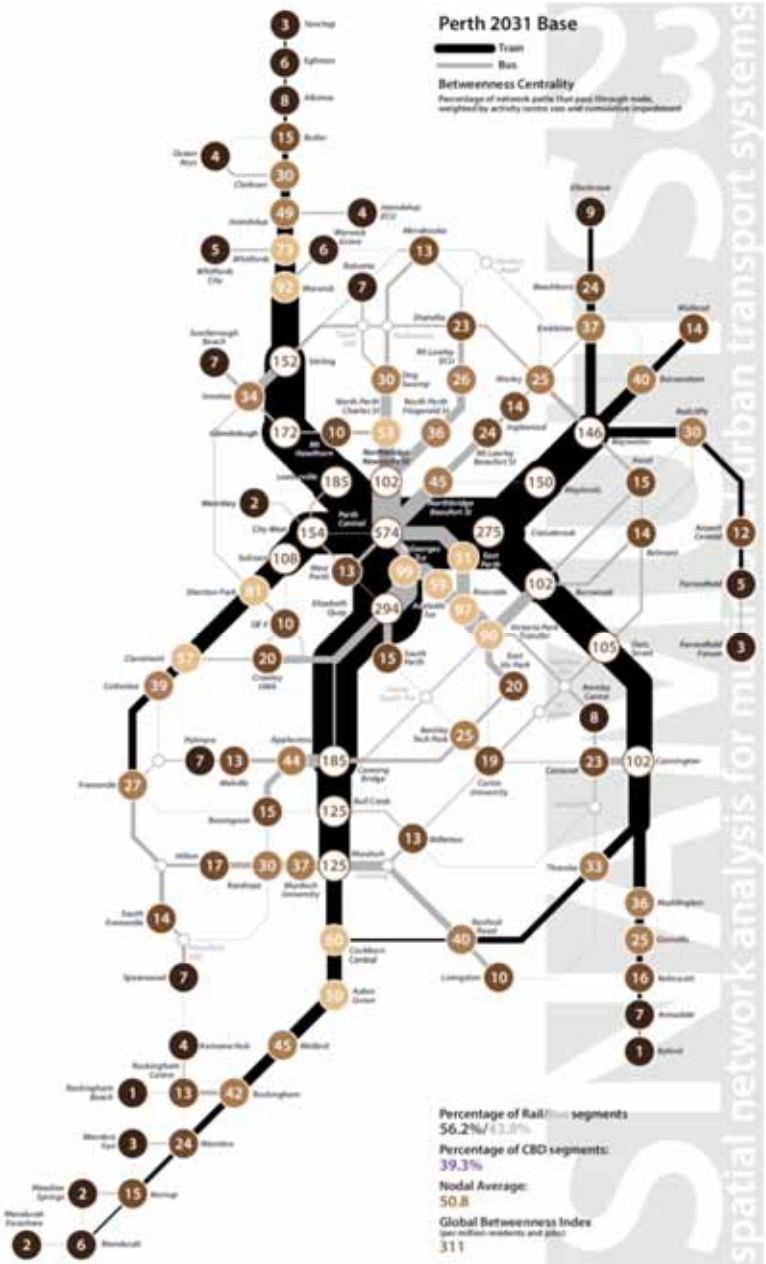

Residential and employment growth additional to 2031 trend along the Trackless Tram corridors
Stirling
+3,250 residents
+7,000 jobs
Innaloo
+3,250 residents
+7,000 jobs
Leederville
+2,500 residents
Glendalough
+5,750 residents
+5,000 jobs
Northbridge
+4,500 residents
Perth Central
+4,500 residents
St Georges Tce
+11,250 residents
+4,000 jobs
Riverside
+4,250 residents
Elizabeth Quay
+11,250 residents
+4,000 jobs
Adelaide Tce
+5,000 residents
+4,000 jobs
Bentley Tech Park
+12,000 residents
+10,000 jobs
Carousel
+10,250 residents
+16,000 jobs
Cannington
+10,250 residents
+16,000 jobs
Curtin University
+23,750 residents
+24,500 jobs

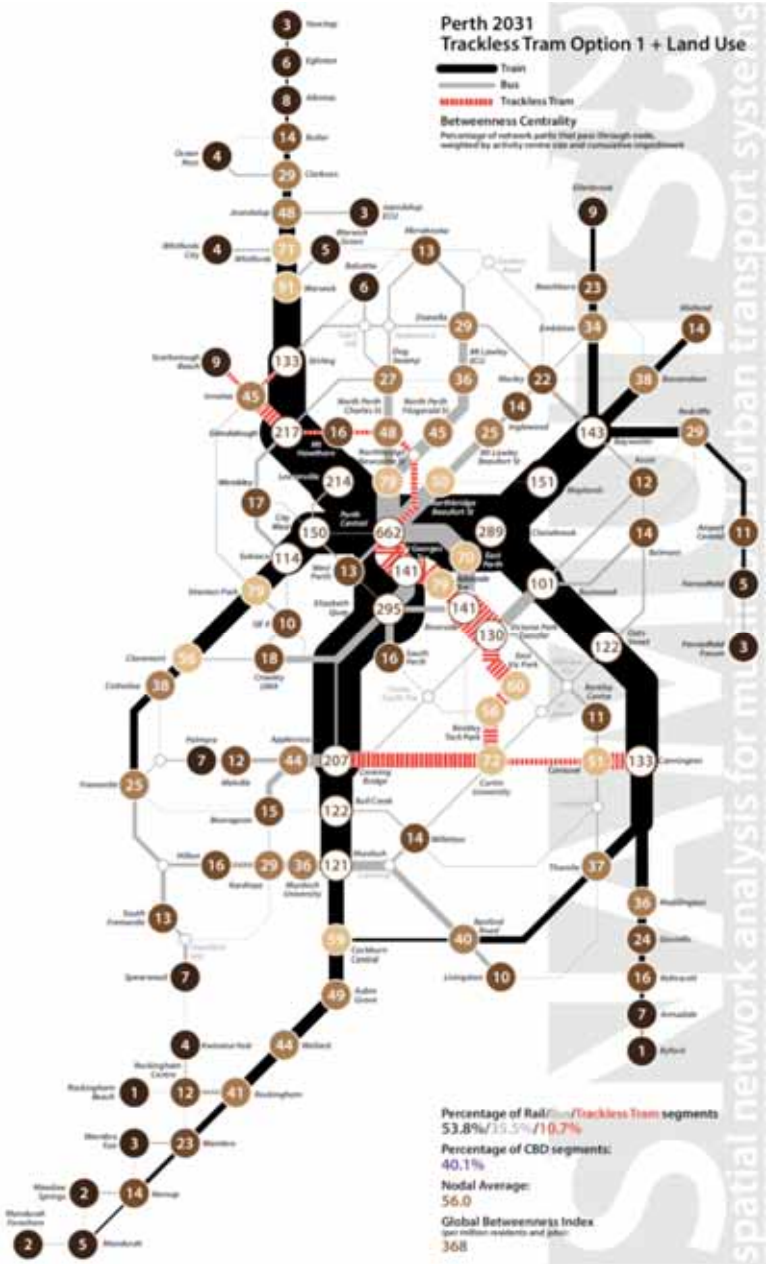

Perth 2031
Trackless Tram Option 1 + Land Use
Train
Bus
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2031 Base, weighted by combined catchment size
Global Efficiency Change:
+25.2%


Perth 2031
Trackless Tram Option 2 + Land Use
Train
Bus
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2031 Base, weighted by combined catchment size
Global Efficiency Change:
+25.6%


Perth 2031
Trackless Tram Option 3 + Land Use
Train
Bus
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2031 Base, weighted by combined catchment size
Global Efficiency Change:
+22.1%

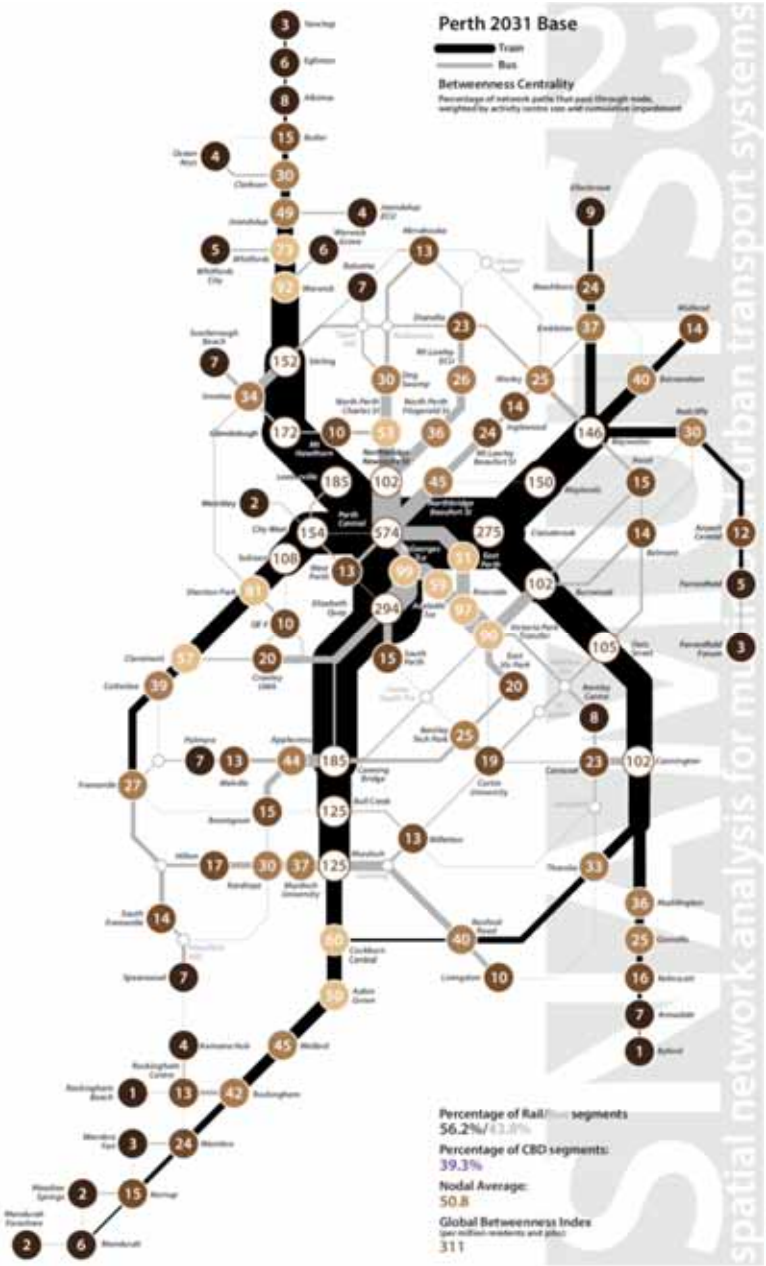
2031 base

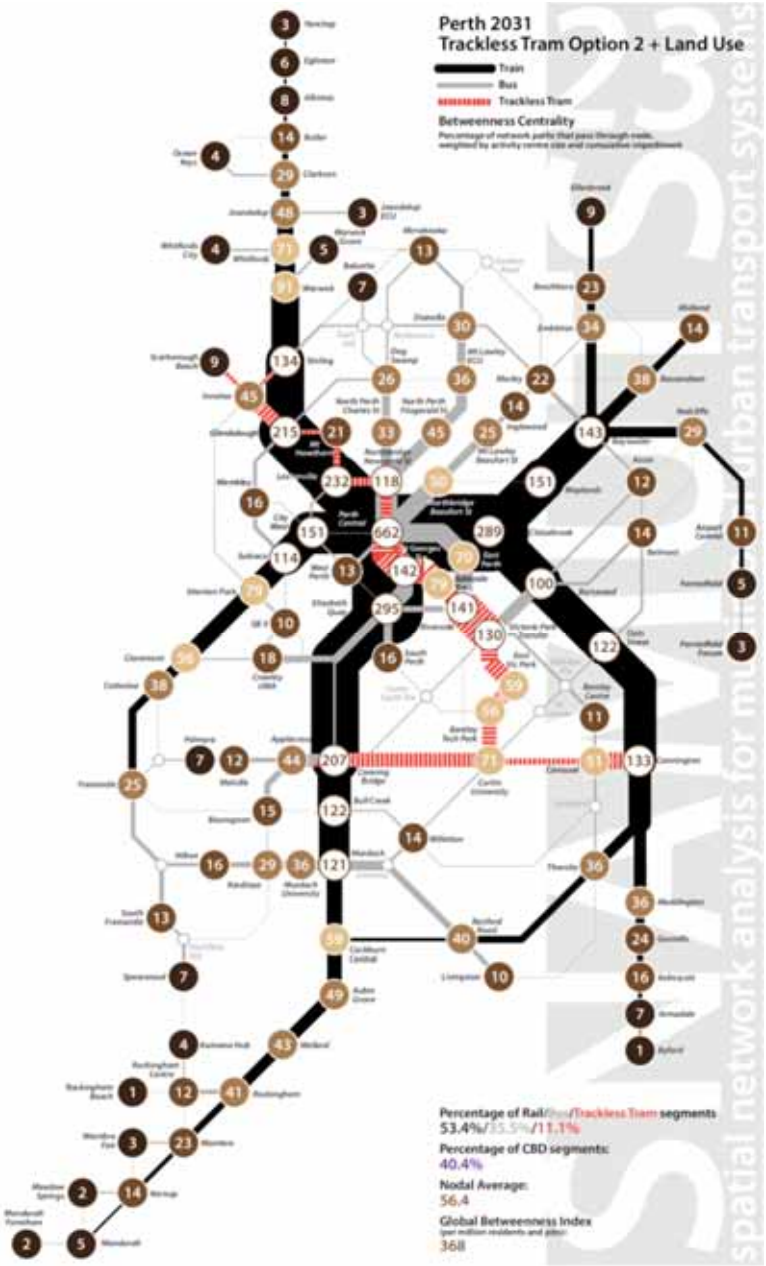




option 1 + land use

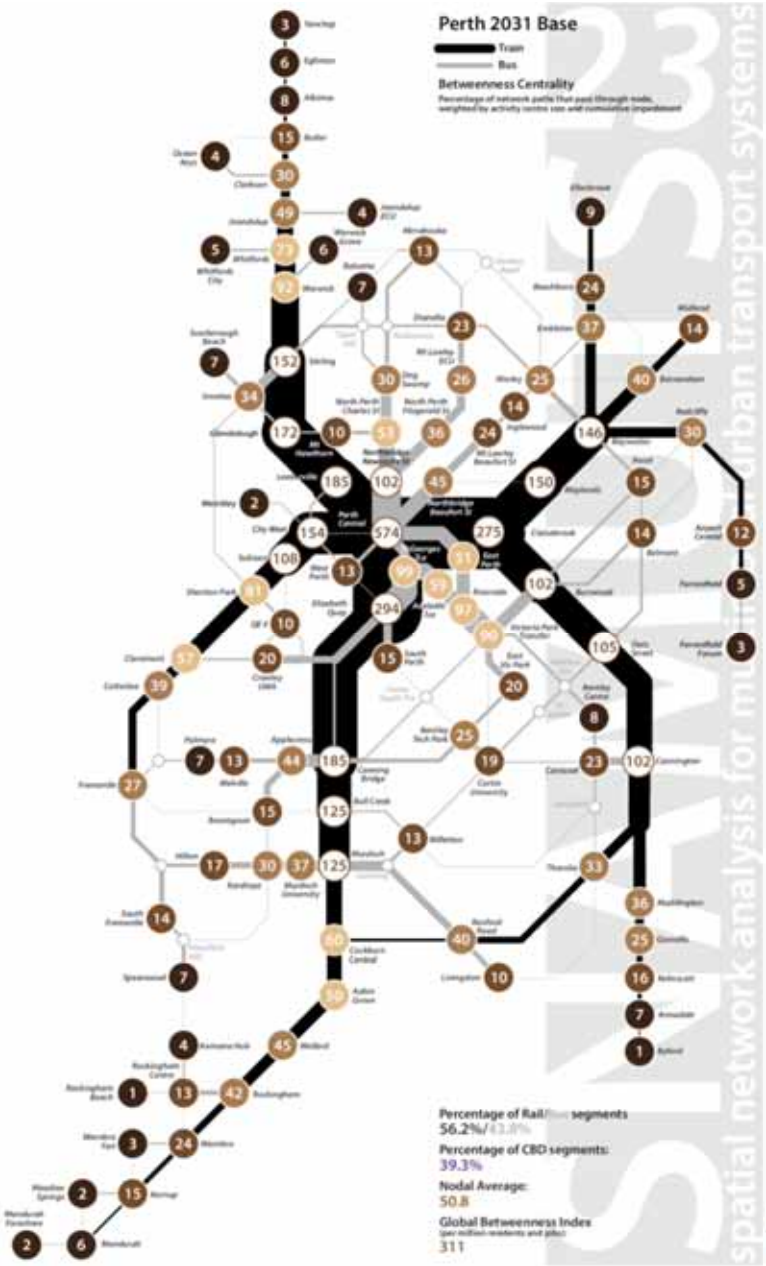
2031 base

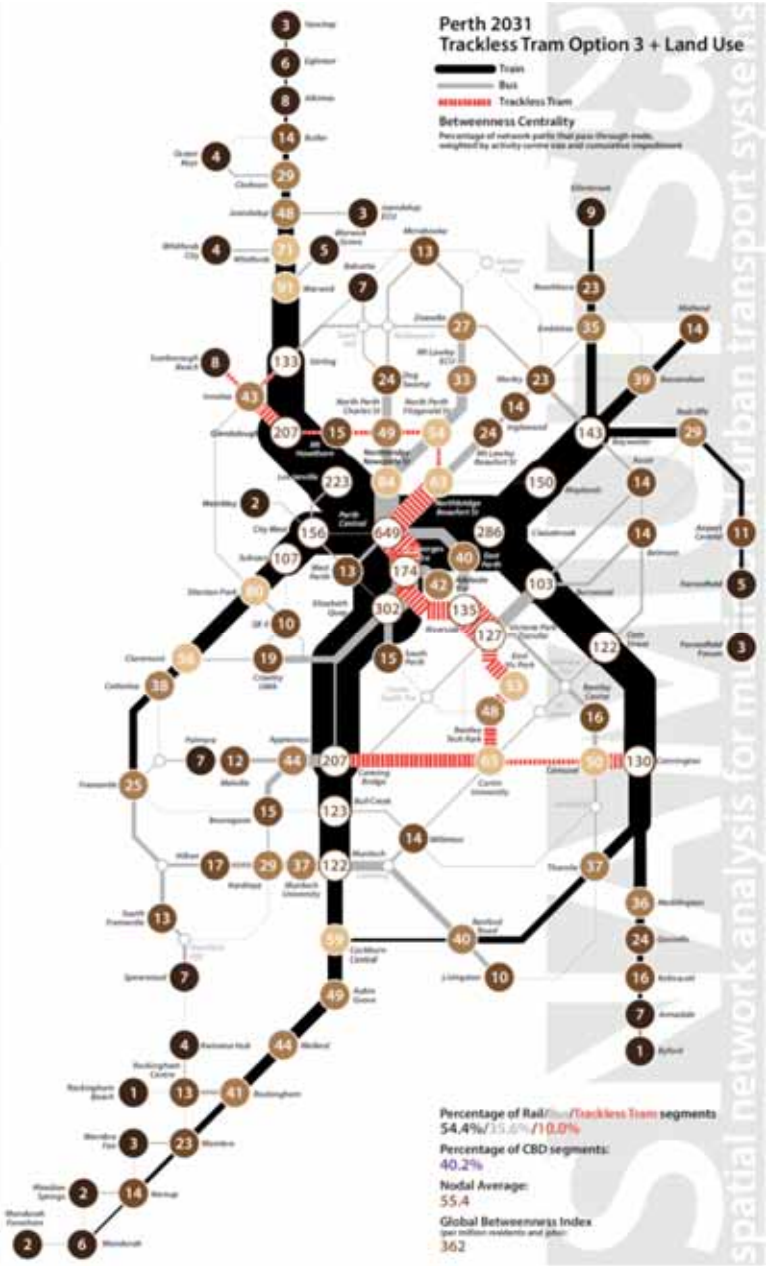




option 2 + land use

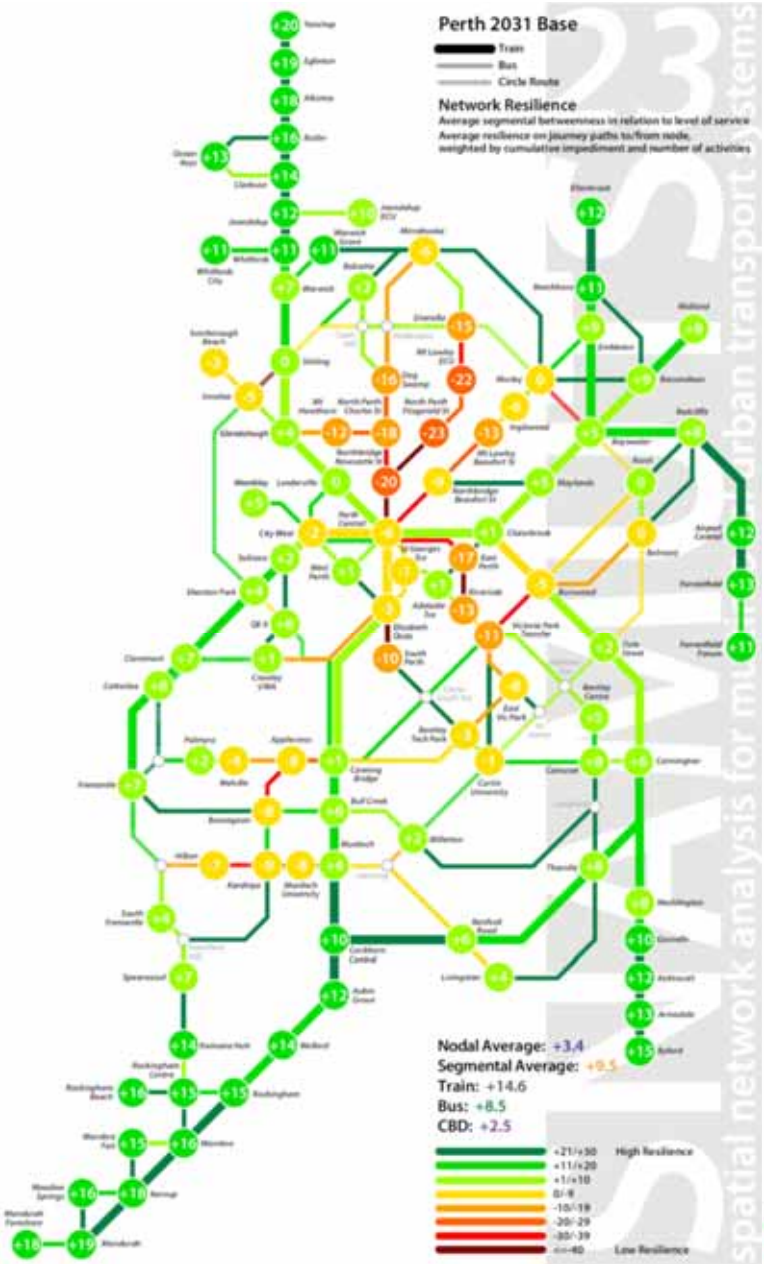
2031 base

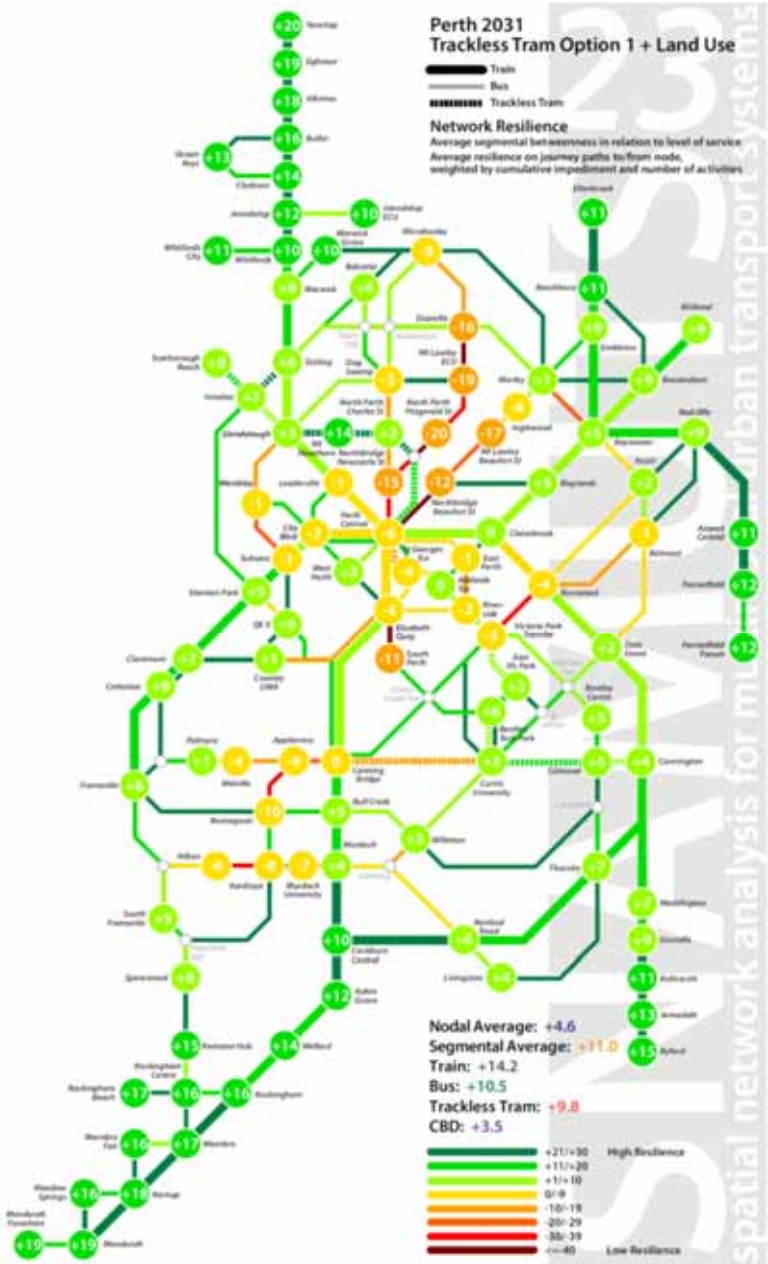




option 3 + land use

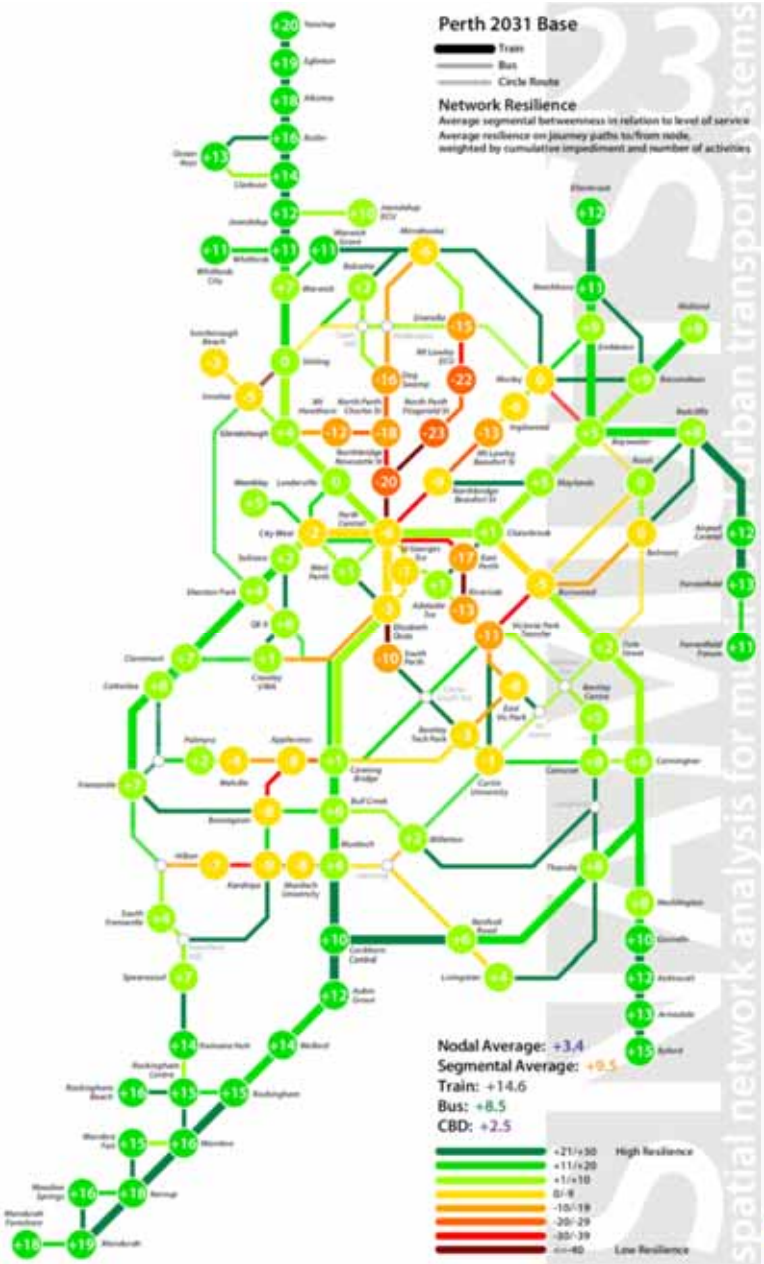
2031 base

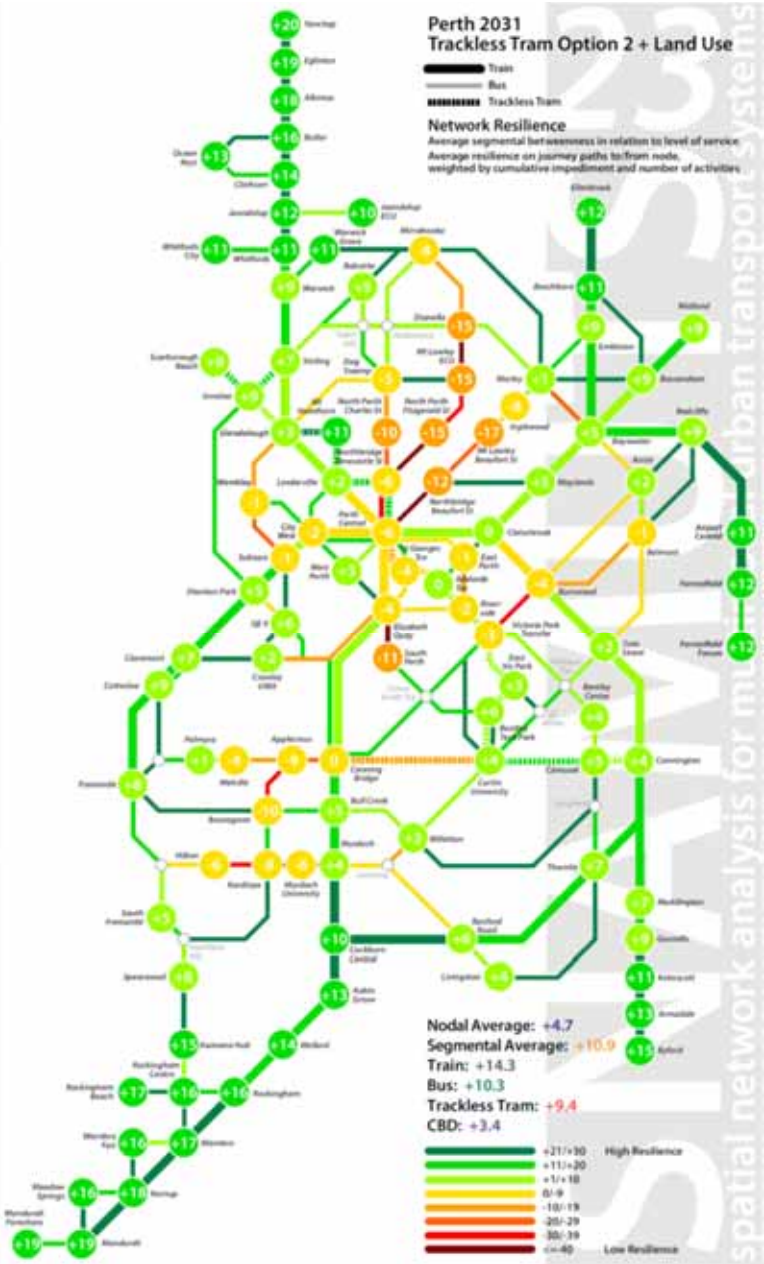




option 1
+
land use

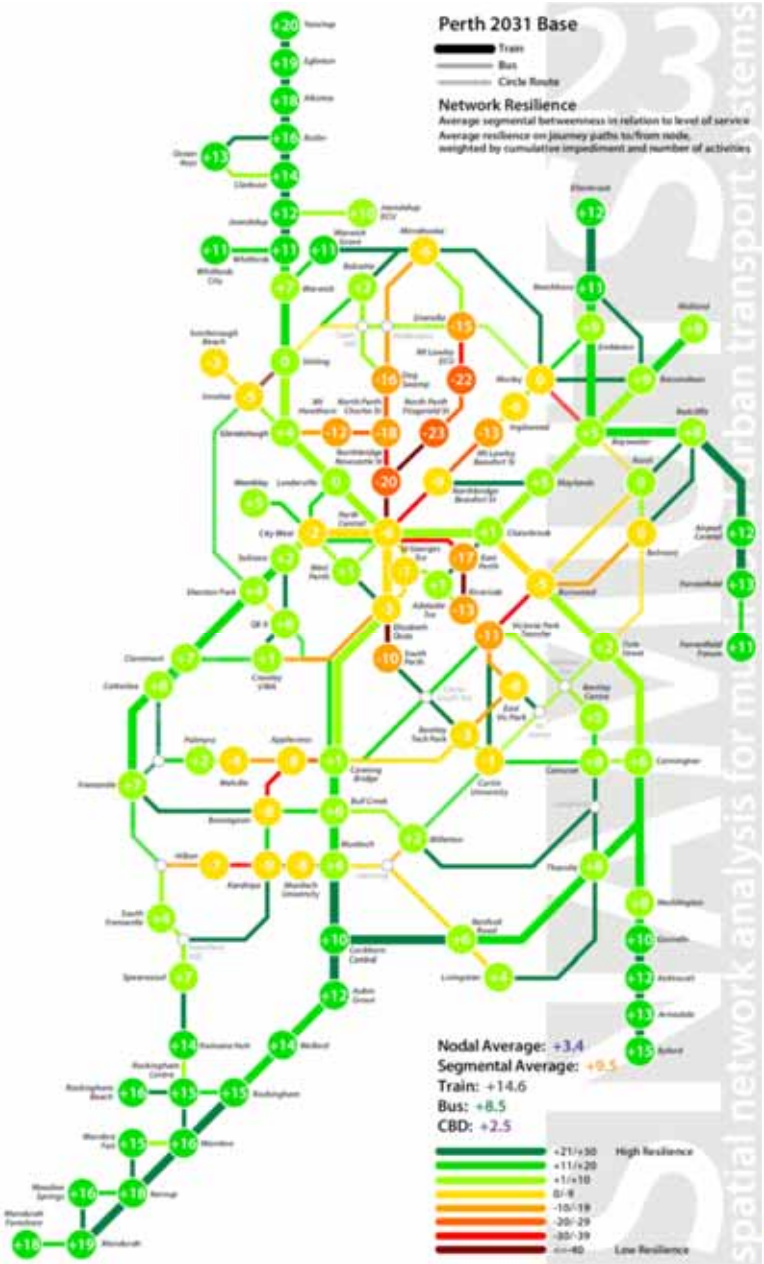
2031 base

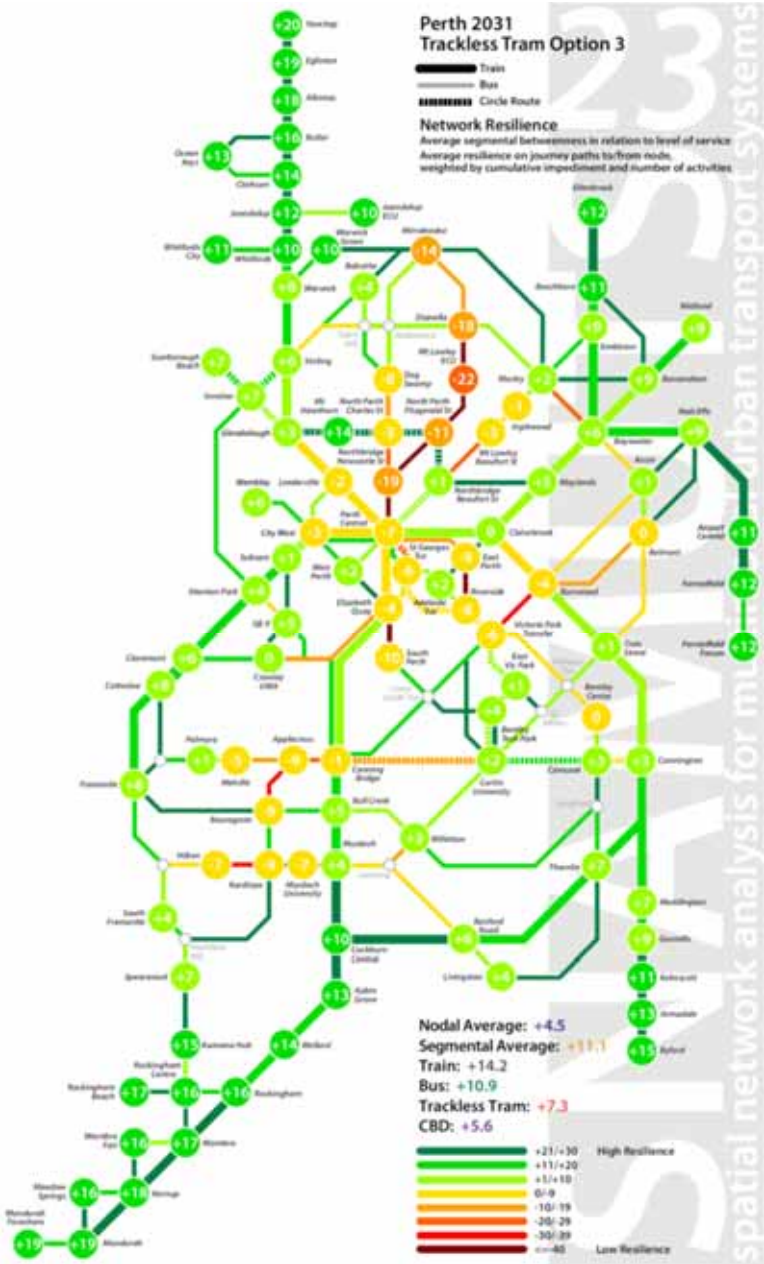




option 2
+
land use

2031 base



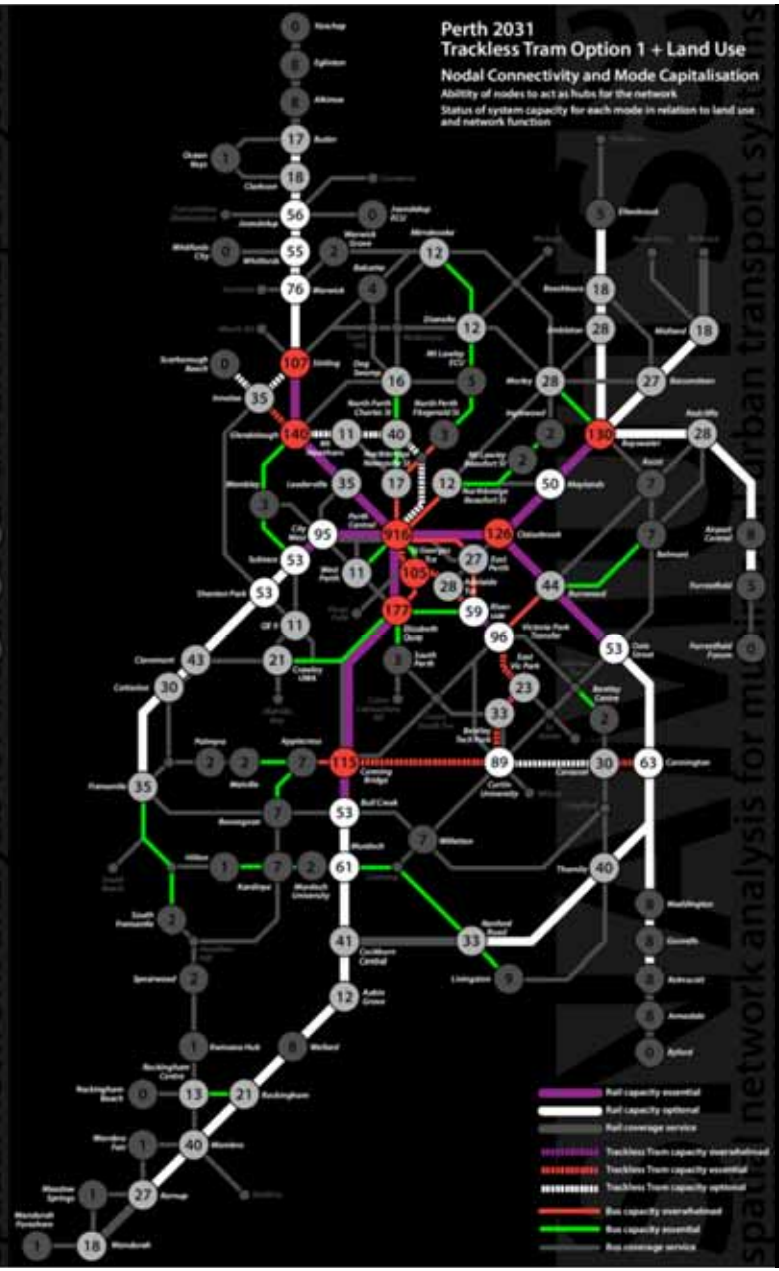


option 3
+
land use

mode capitalisation:

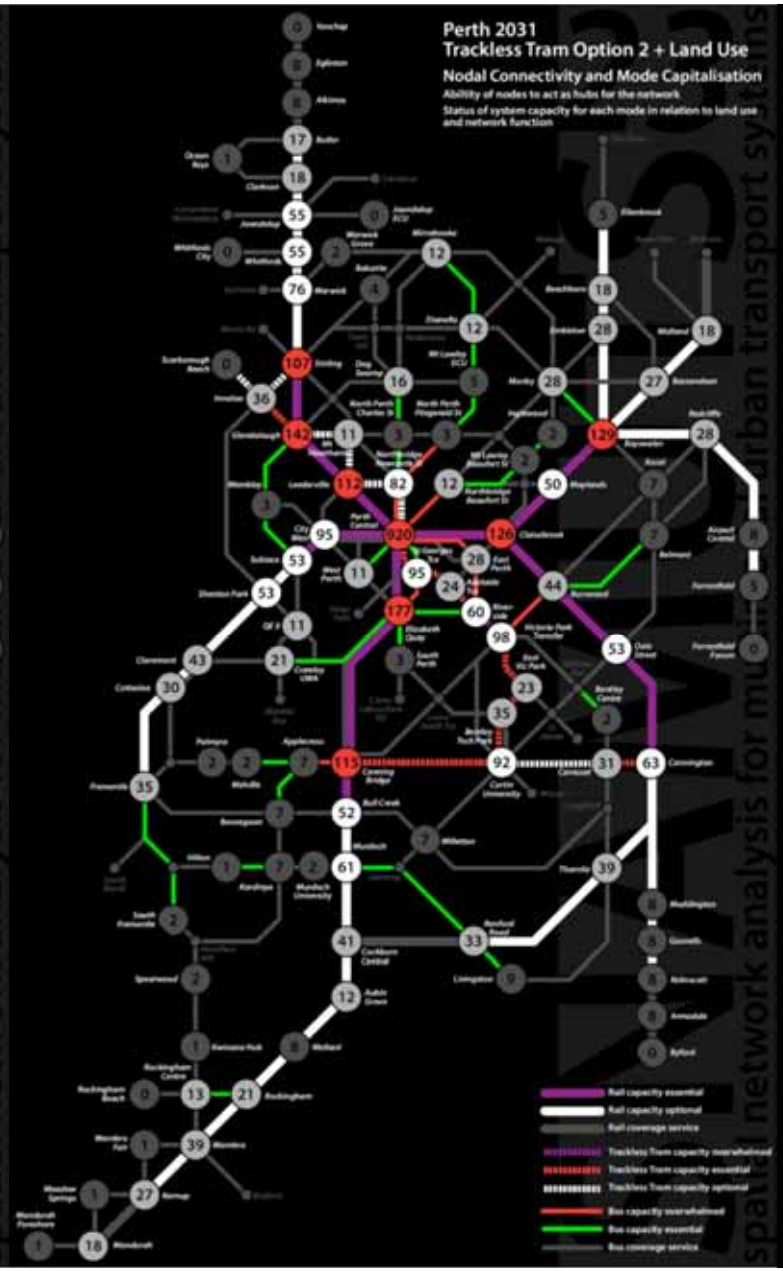
where do perth's proposed trackless tram routes exceed the capacity of a bus system, and where will they be approaching their own capacity limits?

2031
base



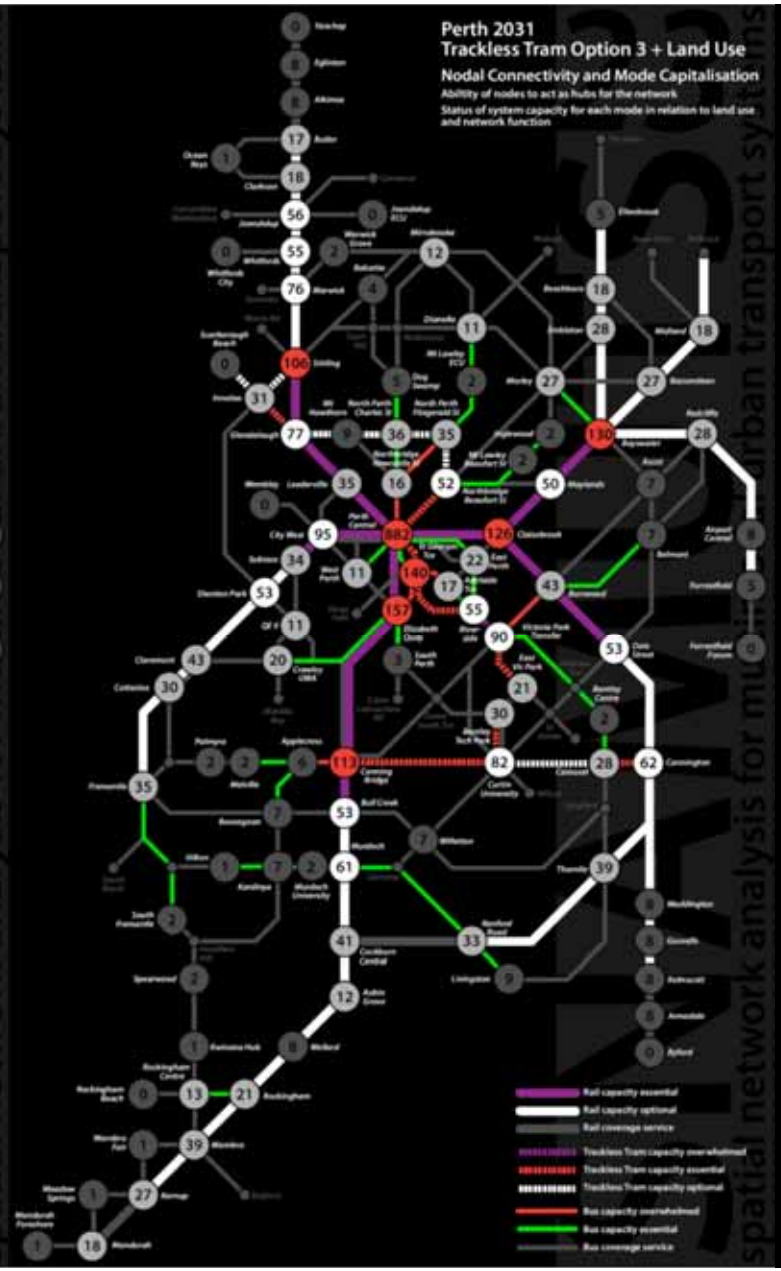
option 1
+
land use

2031
base



option 2
+
land use

2031
base



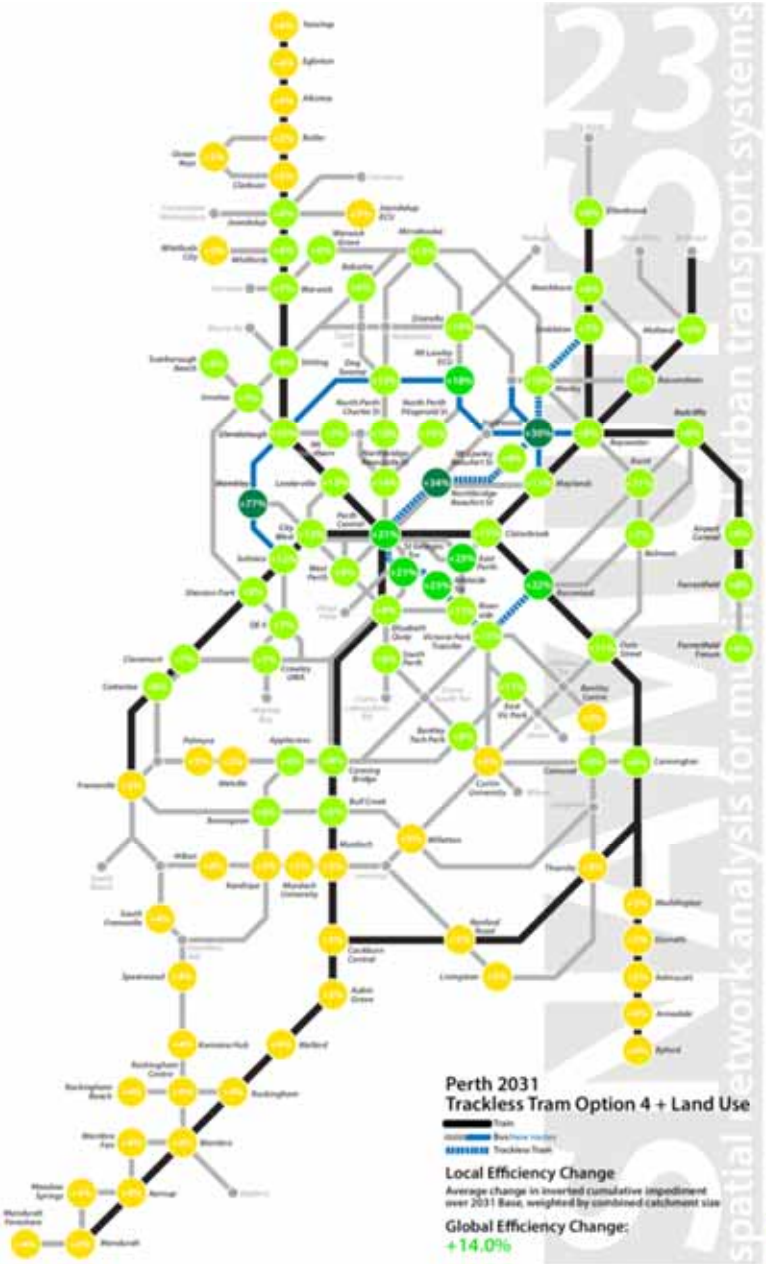
option 3
+
land use

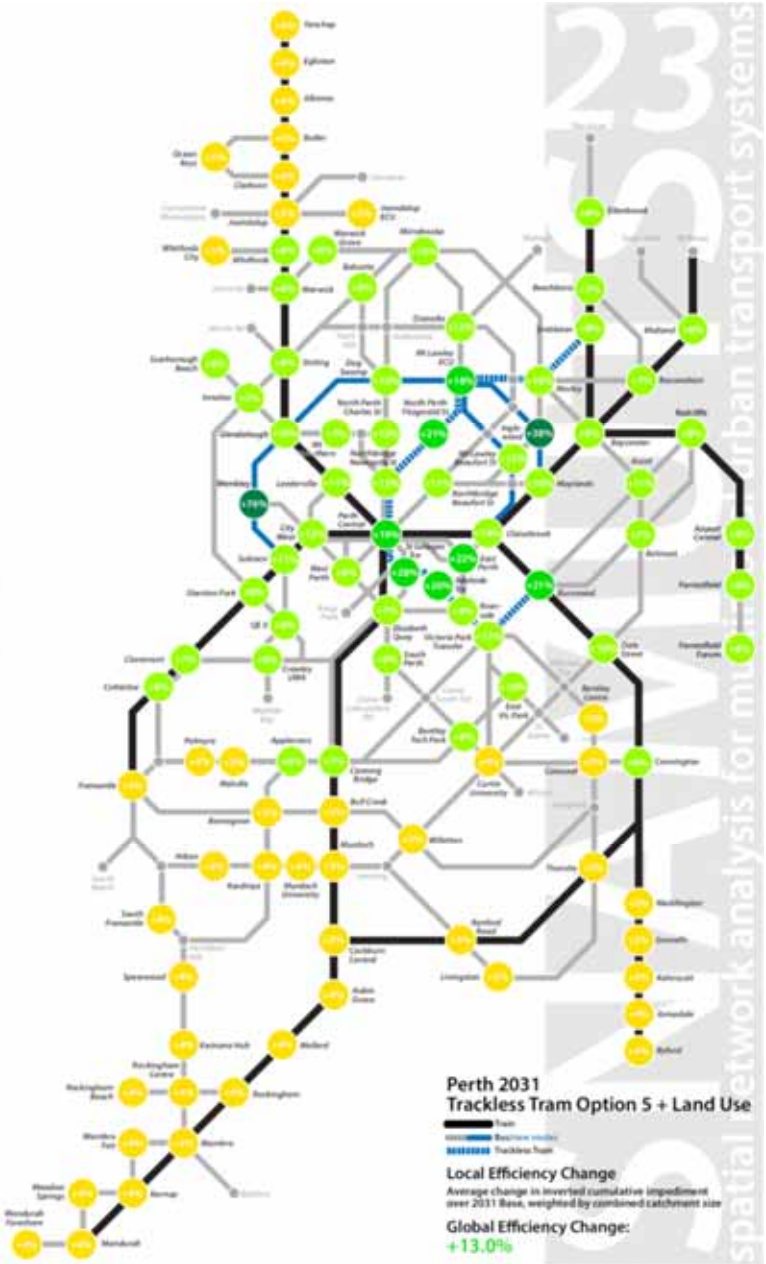
Insights from Scenarios 1, 2 and 3:

- Scenarios 1 and 2 are close variations of each other and perform quite similarly
- Scenario 3 performs more poorly on most indicators than Scenarios 1 and 2, except on resilience – particularly in the central area.
- Keeping Trackless tram services resilient means assuming daytime frequencies higher than every 10 minutes (6 2/3 minutes in Scenarios 1 and 2, 7 1/2 minutes in Scenario 3 – and every 3-5 minutes once land use intensification has been added)
- All scenarios show that the CBD-Victoria Park section is already worthy of Medium Capacity Transit under current land use trends. In the Stirling and Victoria Park-Canning area, dedicated land use intensification strategies are required to achieve this. (In Canning, this becomes imperative to justify a Trackless Tram in addition to the existing – faster – rail access.)
- The Causeway crossing is close to its combined Trackless Tram-bus capacity limit in all scenarios with land use intensification, suggesting the need for an additional public transport river crossing soon after 2031

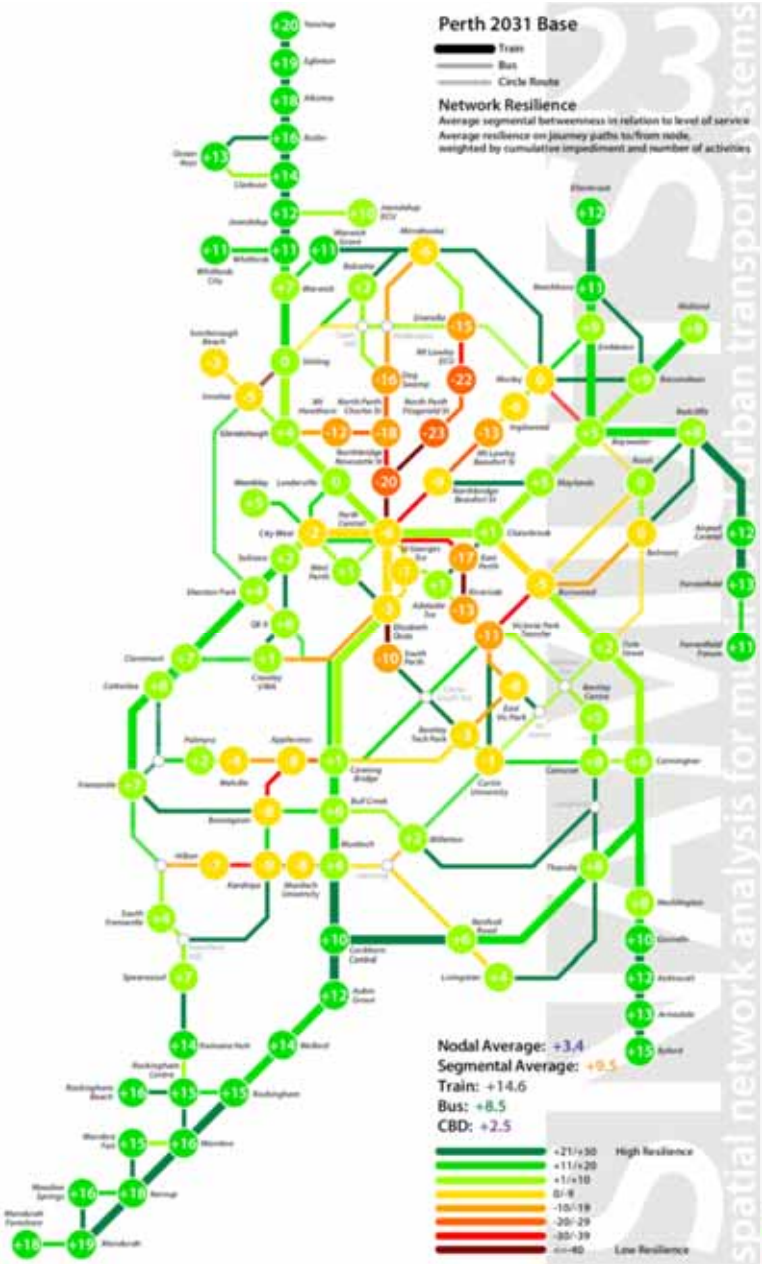
what if:

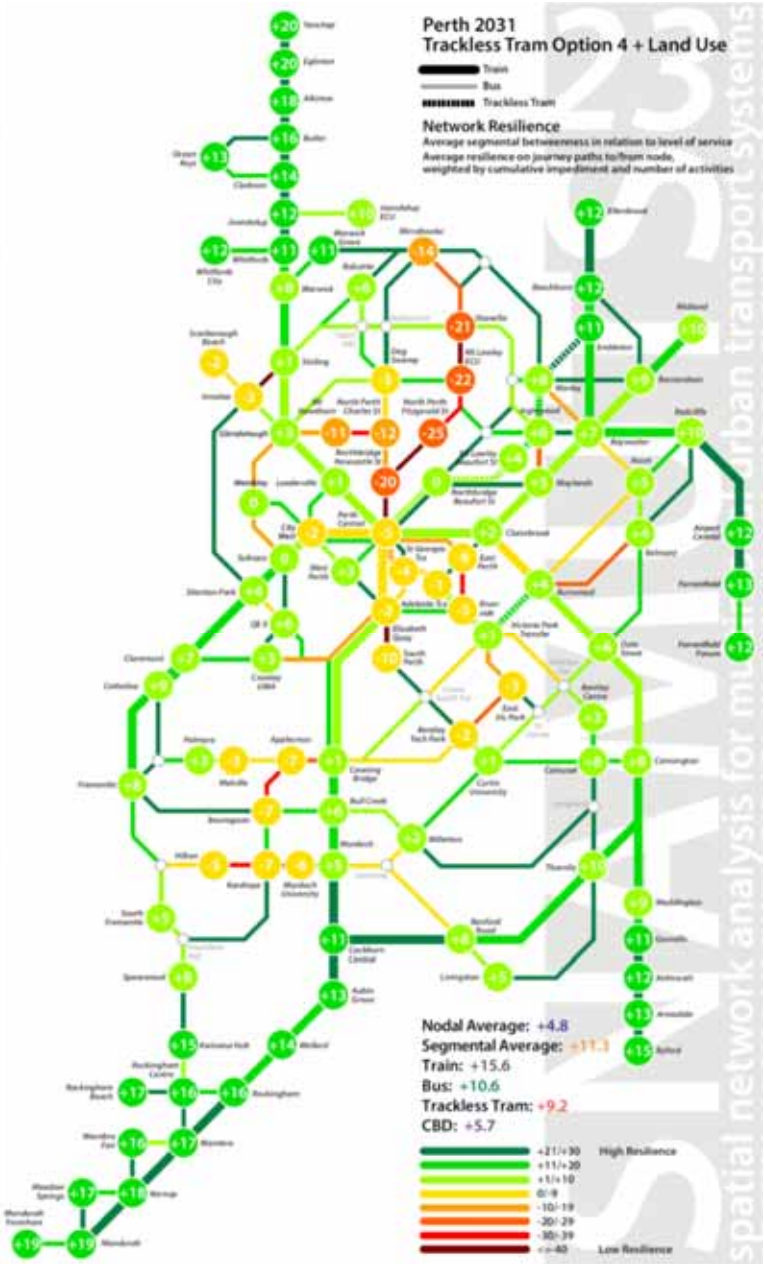
the first route went to the northeast, rather than the northwest and southeast?


Perth 2031
Trackless Tram Option 4 + Land Use
Train
Bus/new routes
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2031 Base, weighted by combined catchment size
Global Efficiency Change:
+14.0%


Perth 2031
Trackless Tram Option 5 + Land Use
Train
Bus/new routes
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2031 Base, weighted by combined catchment size
Global Efficiency Change:
+13.0%

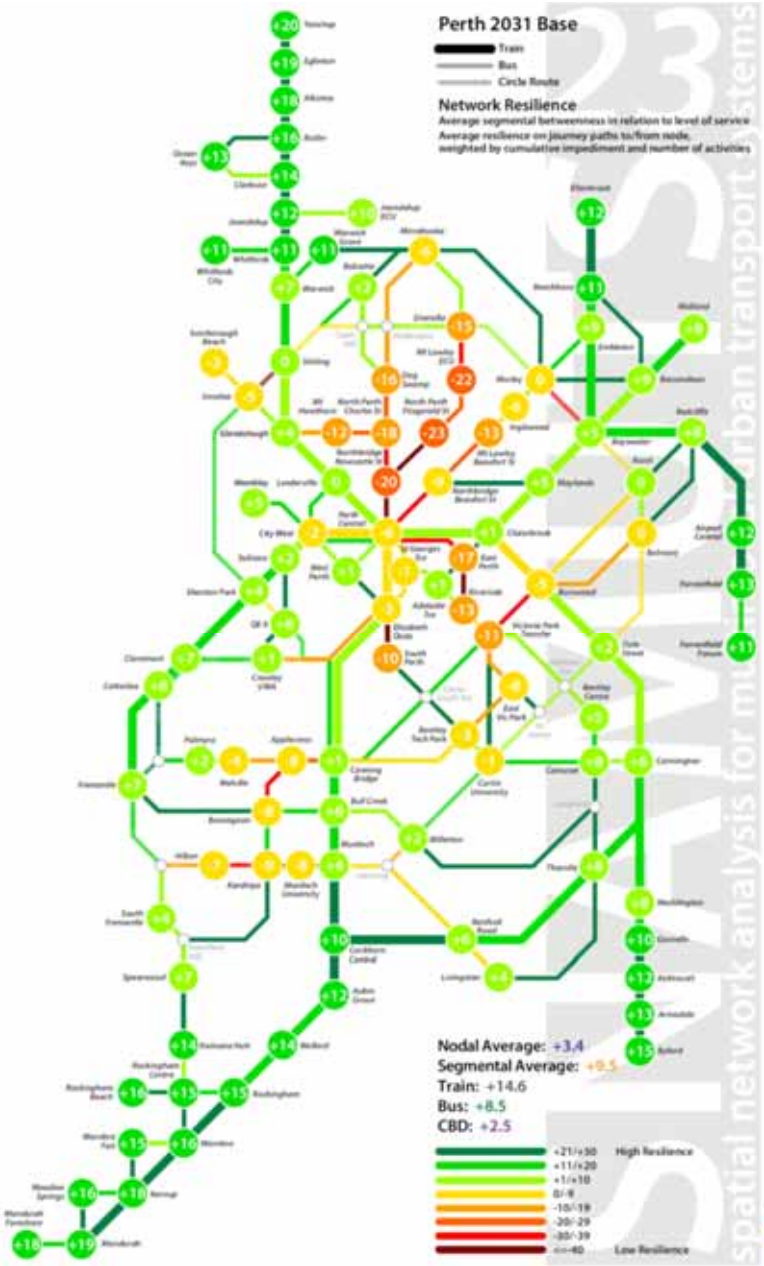
2031 base

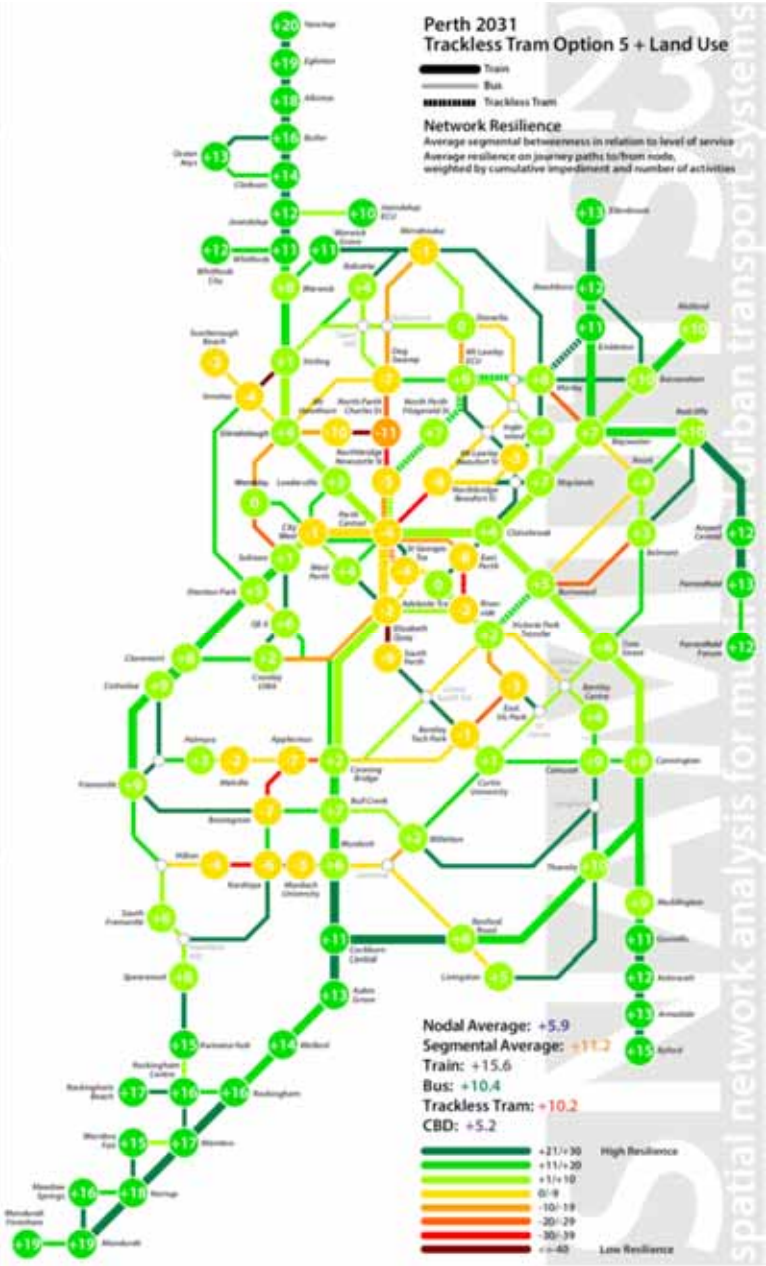




option 4
+
land use

2031 base



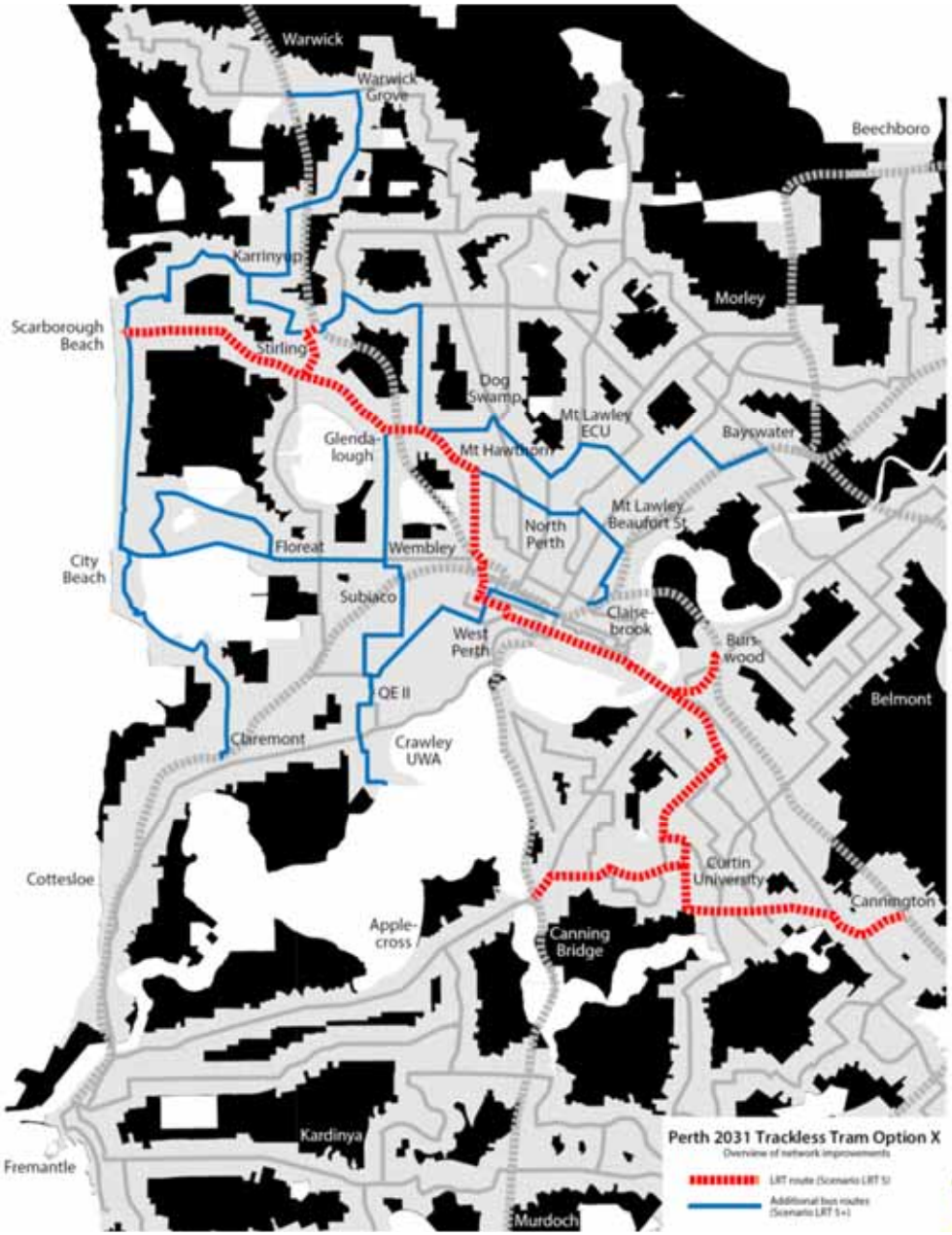


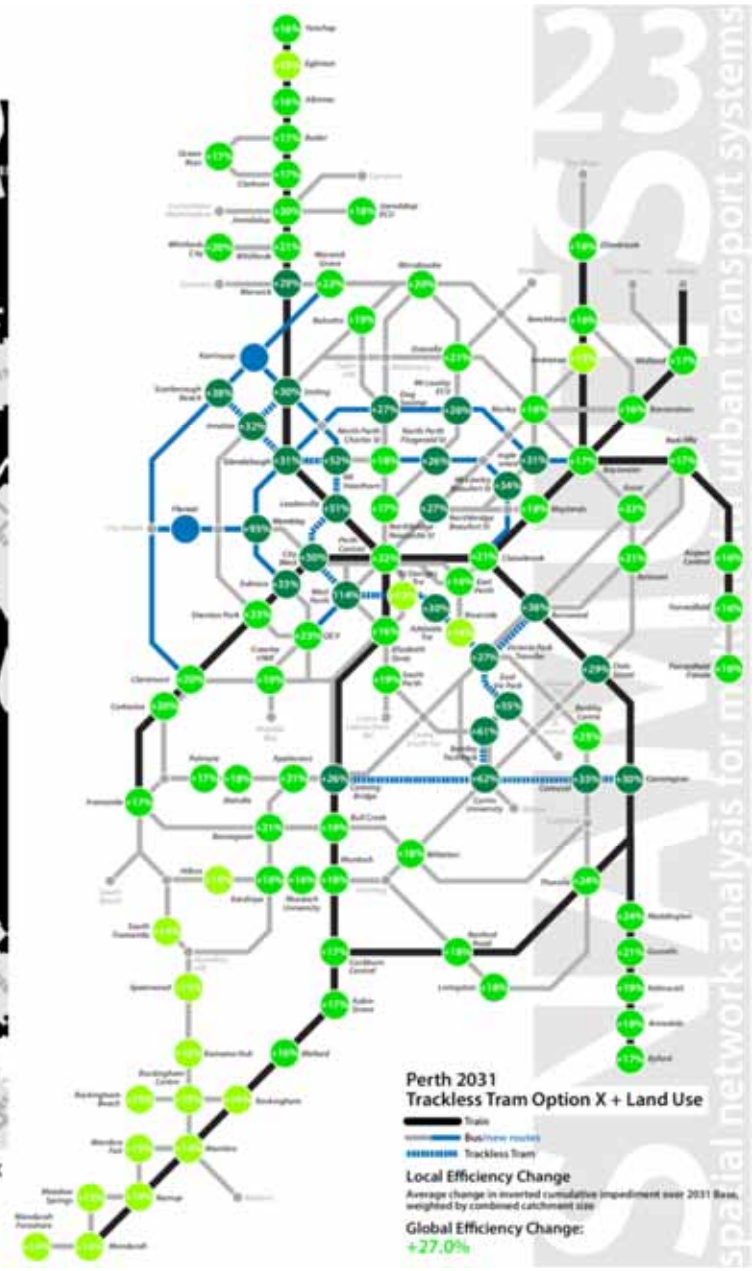
option 5 + land use

what if:

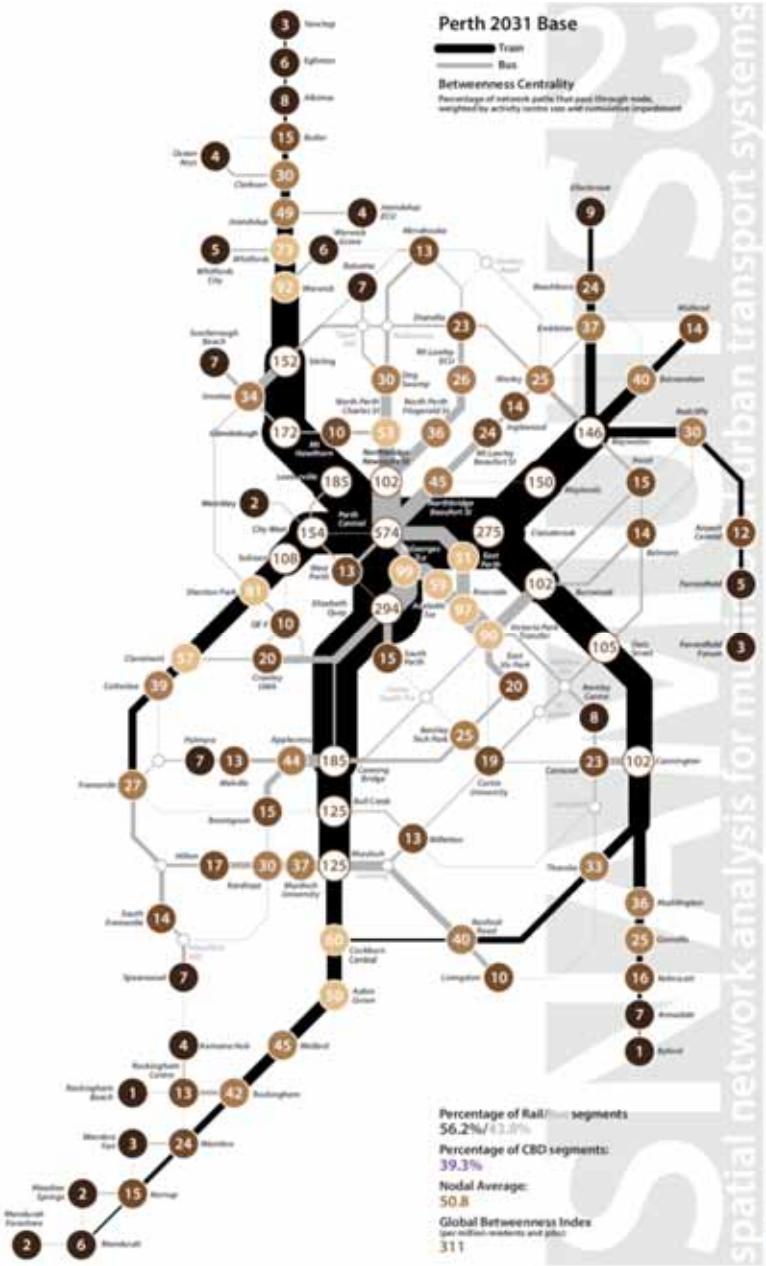
we created a high-frequency east-west trackless tram corridor through the cbd to replace all radial bus routes along the terraces?

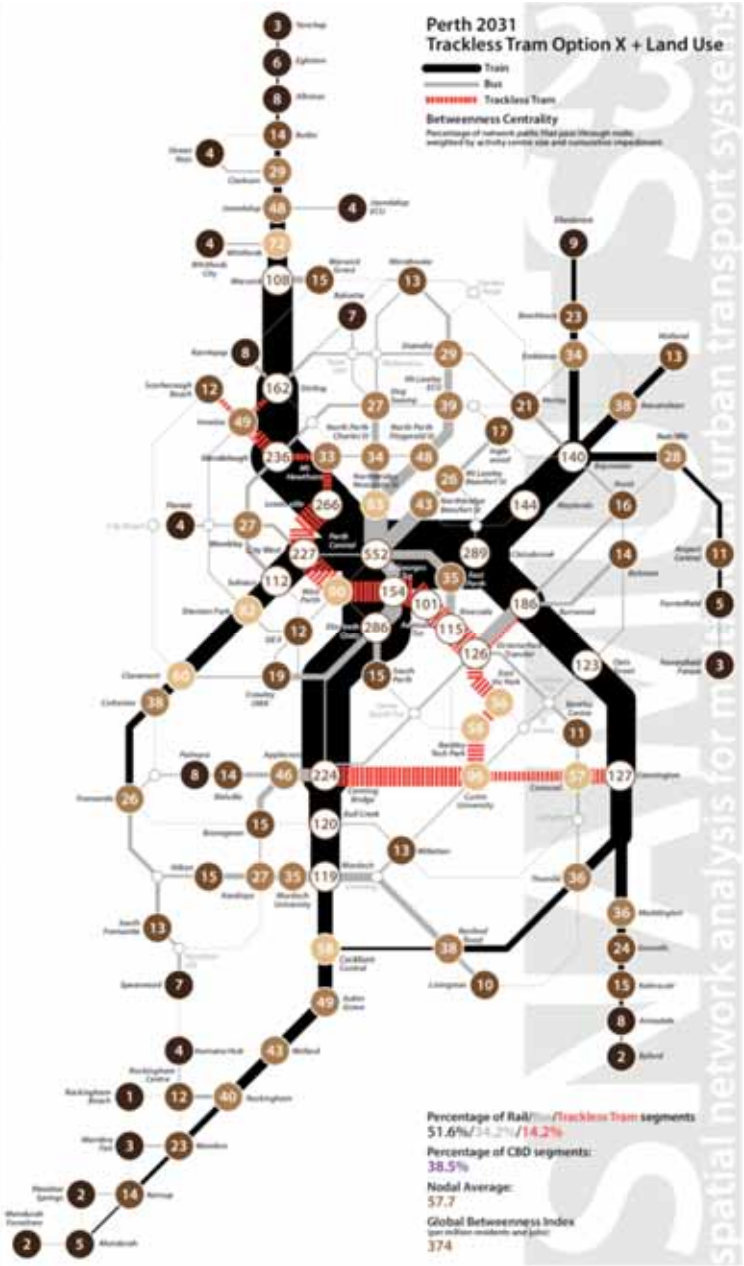

Employment density in Perth's CBD, 2016 (jobs per sq km)
Source: ABS census
Density
< 20000
20000 - 40000
40000 - 60000
60000 - 80000
80000 - 100000
100000 - 120000
120000 - 140000
140000 - 160000
160000 - 180000


Warwick
Warwick Grove
Beechboro
Karrinyup
Morley
Scarborough Beach
Stirling
Dog Swamp
Mt Lawley ECU
Bayswater
Glenda-lough
Mt Hawthorn
Mt Lawley Beaufort St
North Perth
Floreat
Wembley
City Beach
Subiaco
Claise-brook
West Perth
Bars-wood
Belmont
OE II
Claremont
Crawley UWA
Cottesloe
Curtin University
Cannington
Apple-cross
Canning Bridge
Kardinya
Fremantle
Murdoch
Perth 2031 Trackless Tram Option X
Overview of network improvements
LRT route (Scenario LRT 5)
Additional bus routes (Scenario LRT 5+)


23
spatial network analysis for multi-urban transport systems
Perth 2031
Trackless Tram Option X + Land Use
Train
Bus/new routes
Trackless Tram
Local Efficiency Change
Average change in inverted cumulative impediment over 2031 Base, weighted by combined catchment size
Global Efficiency Change:
+27.0%

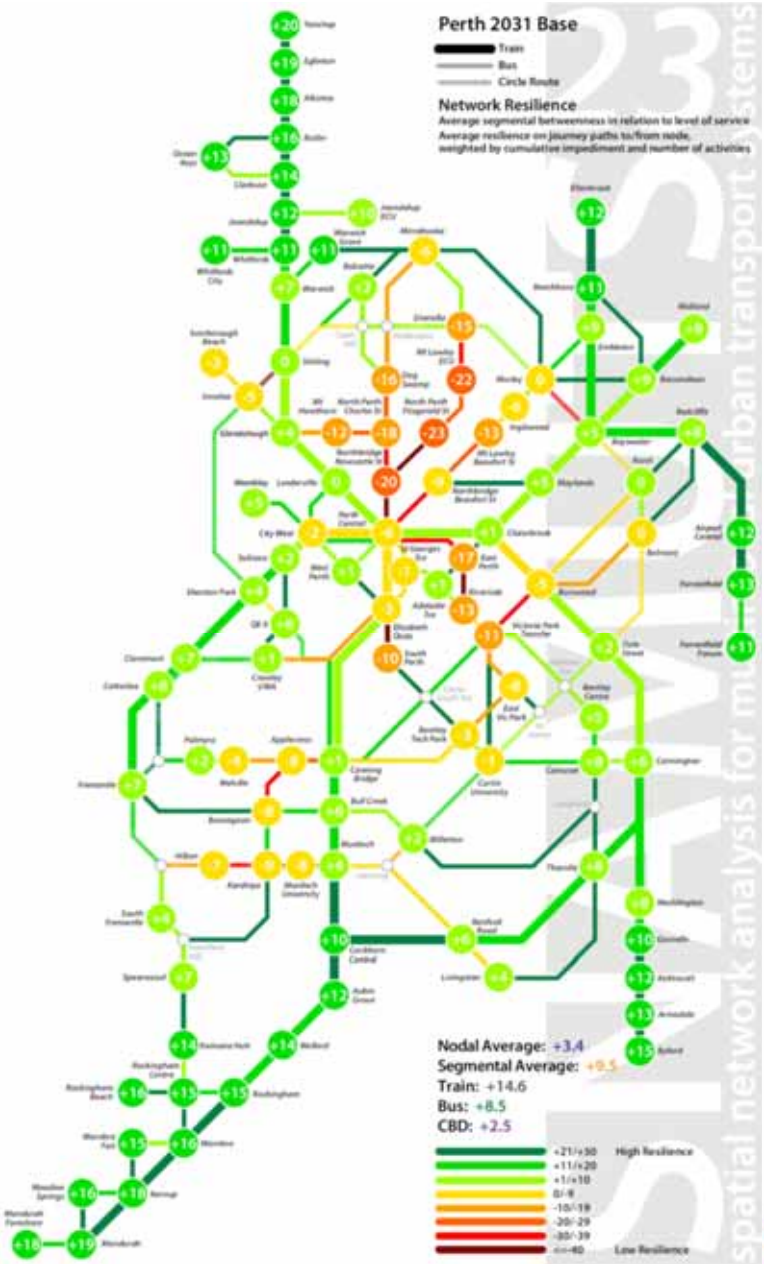
2031 base





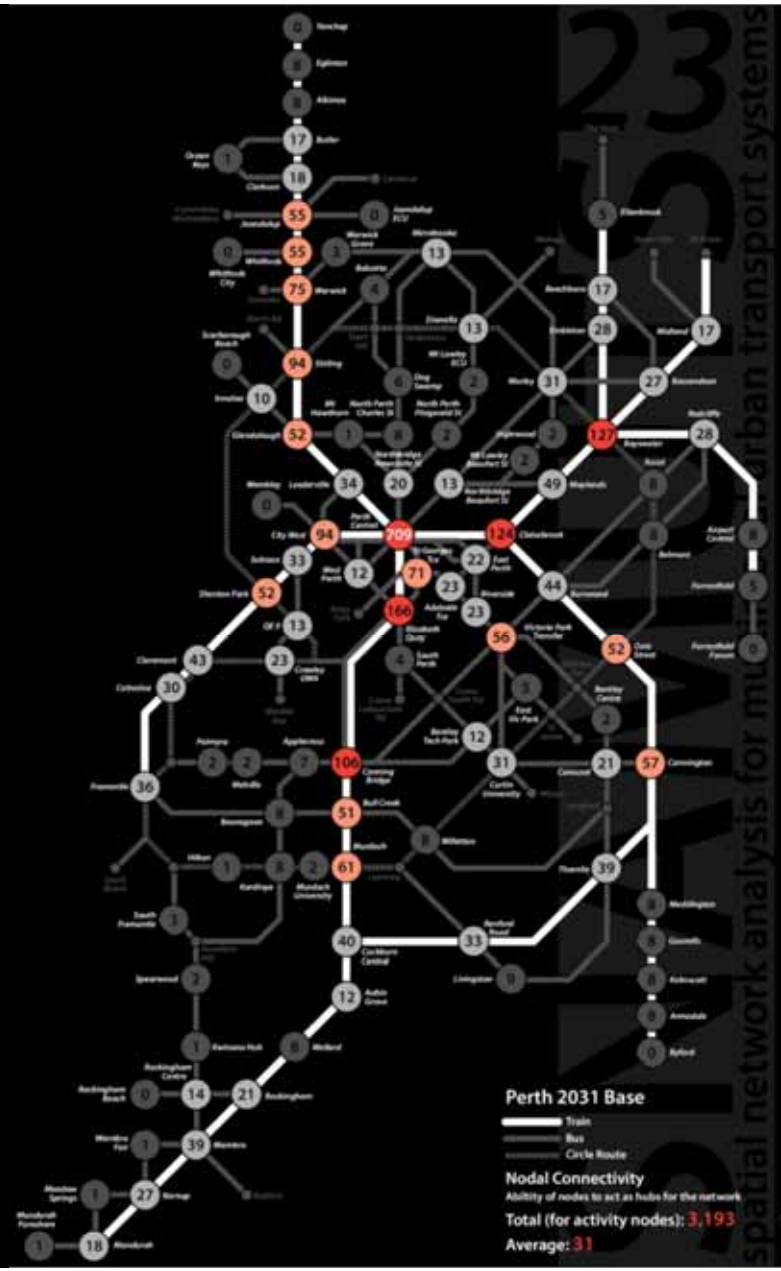
option x
+
land use

2031 base



option x
+
land use

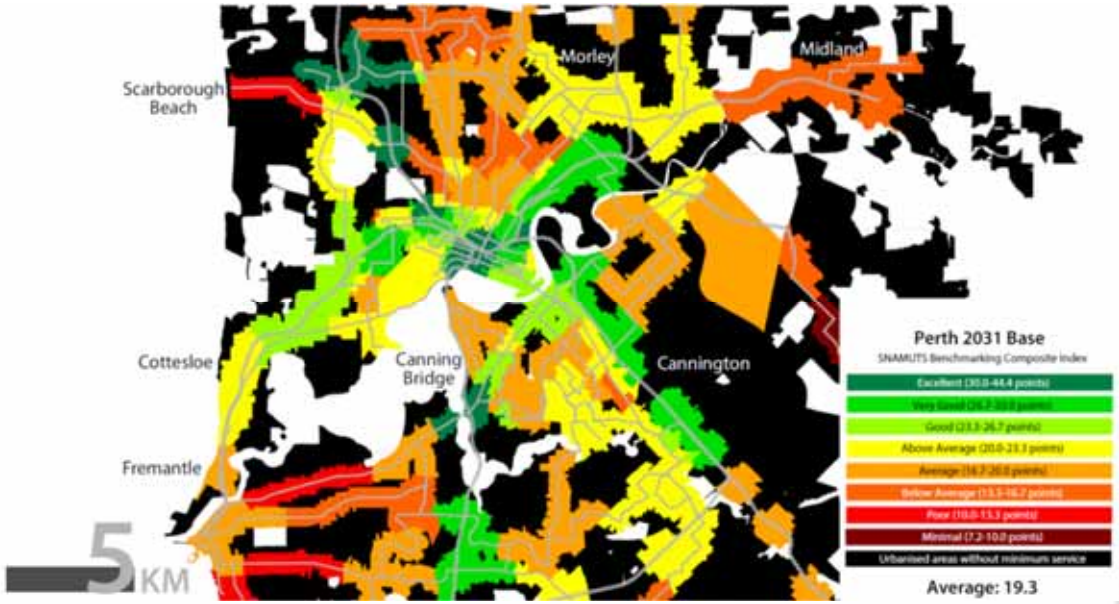
2031
base

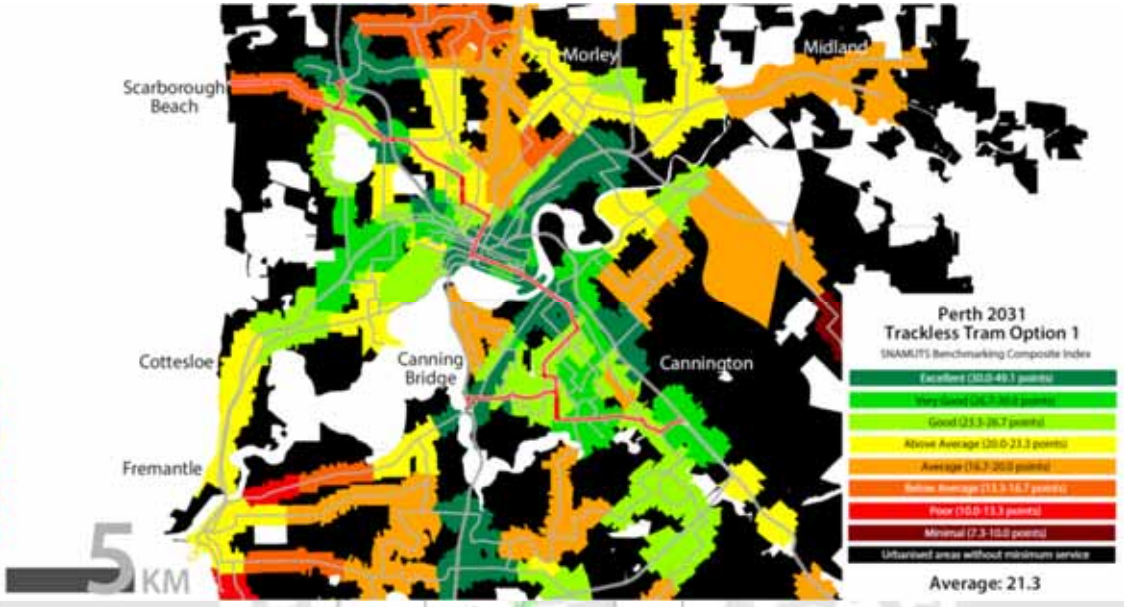


option x
+
land use

snamuts composite index:

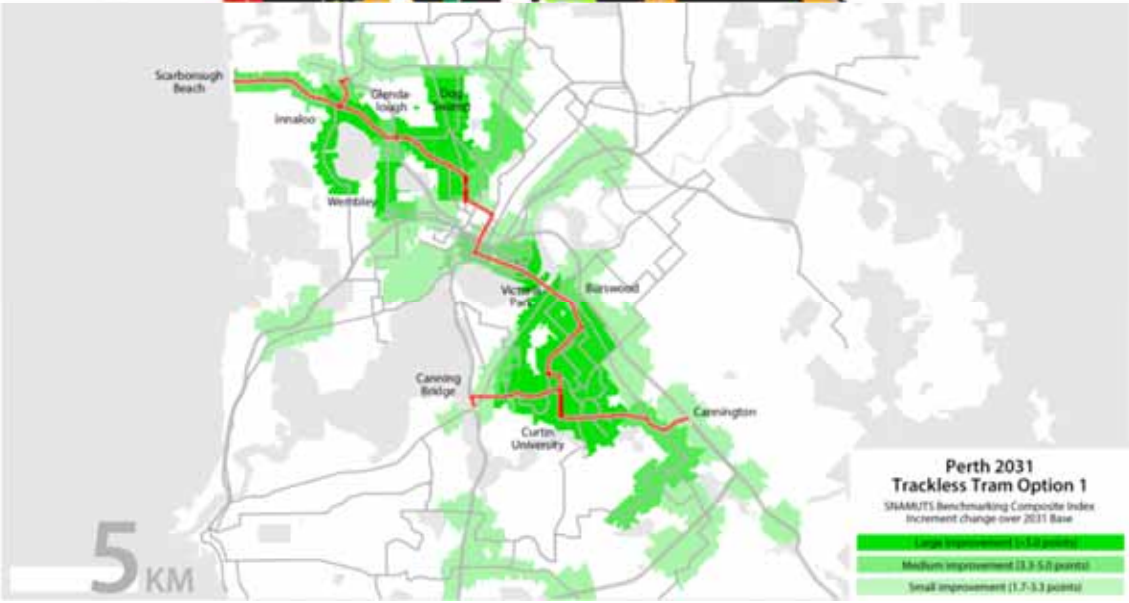
perth's geography of public transport accessibility at a glance. where does it improve the most in each scenario?

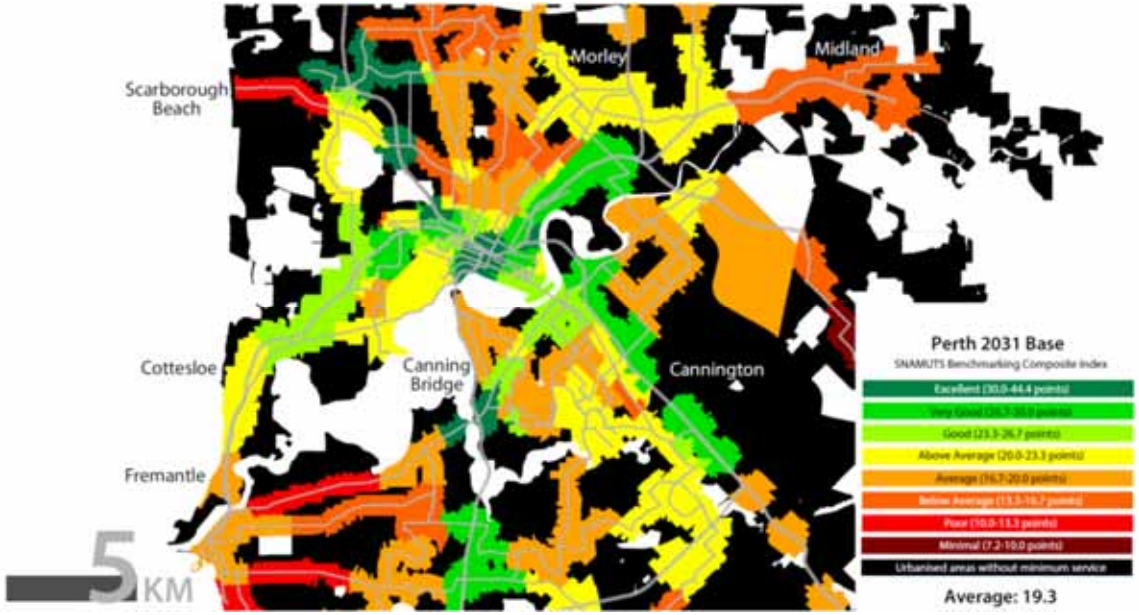




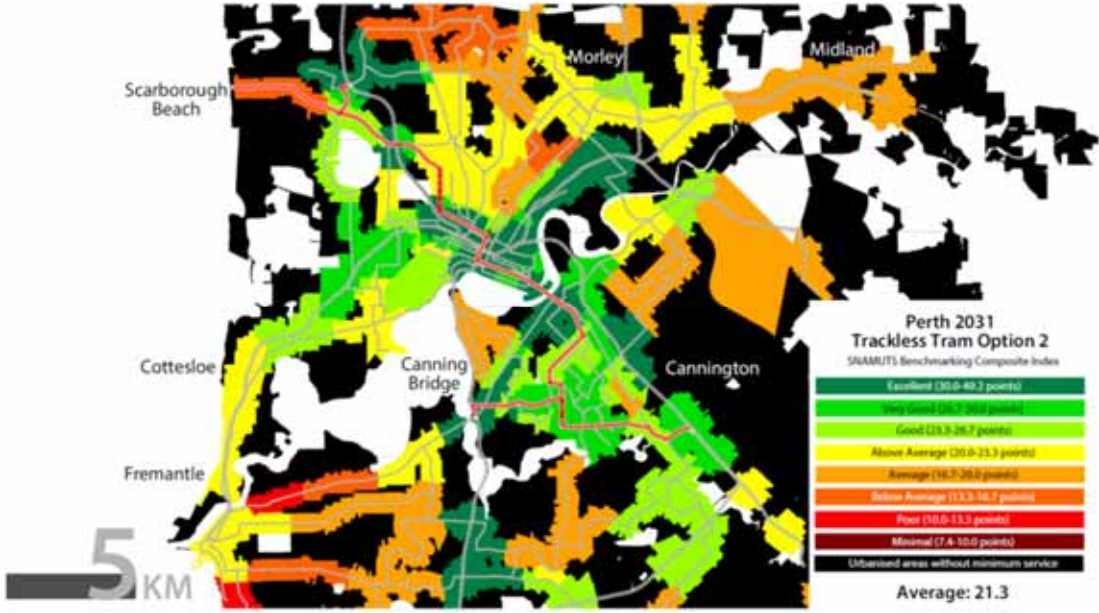
2031 base

option 1
+
land use

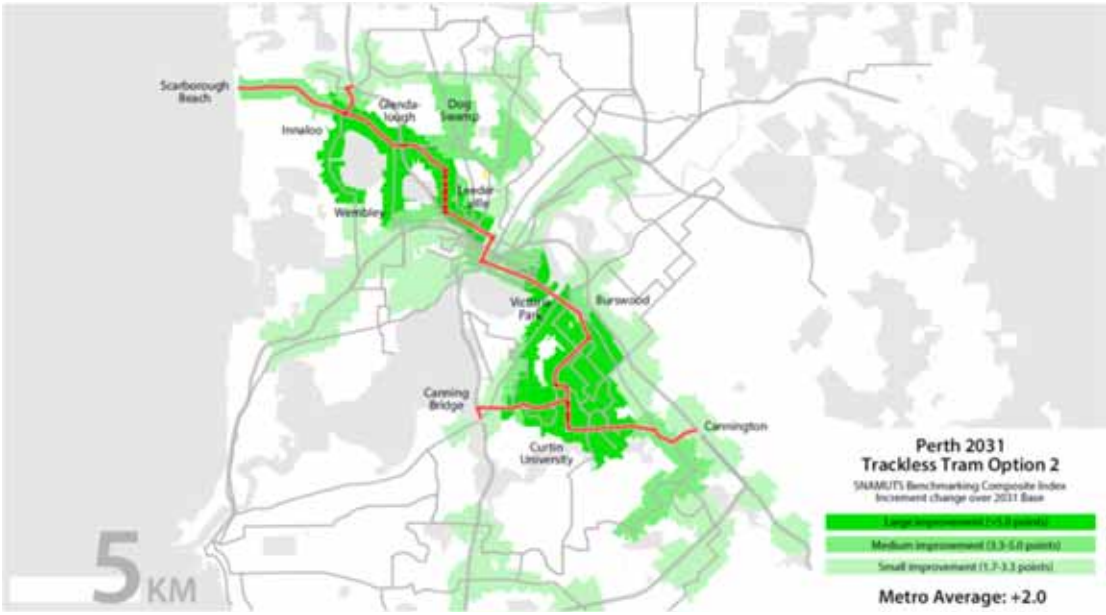


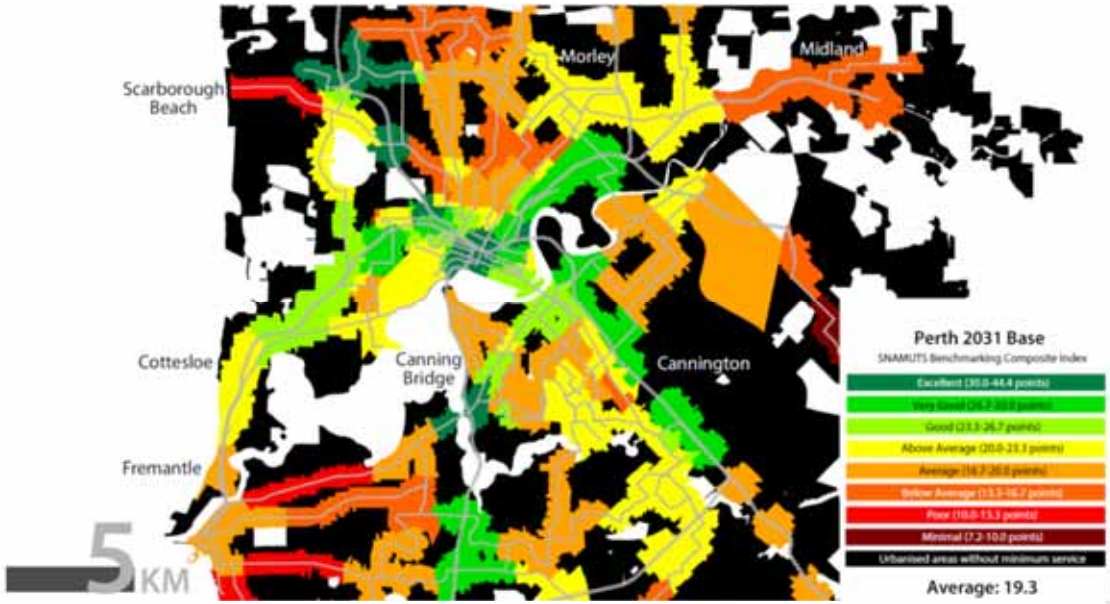


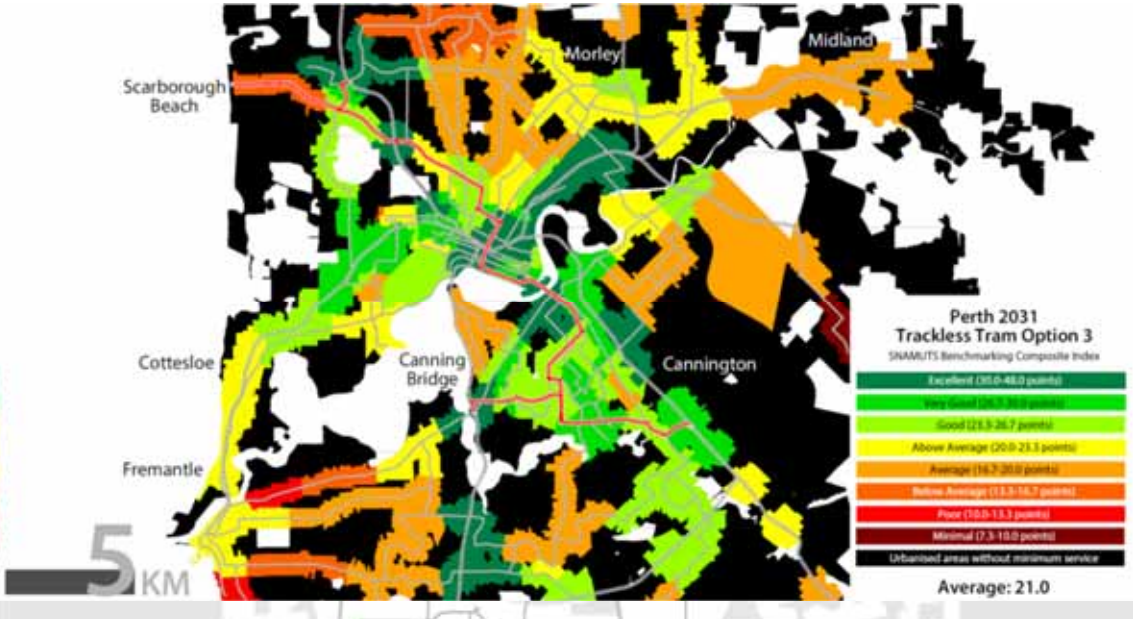
2031 base



option 2
+
land use

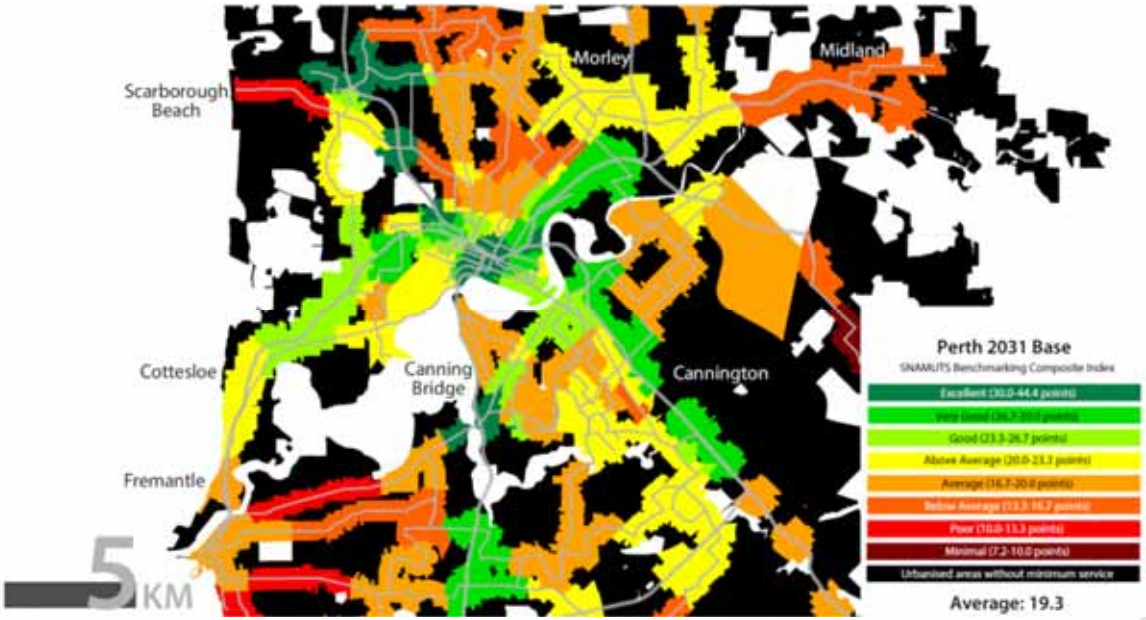




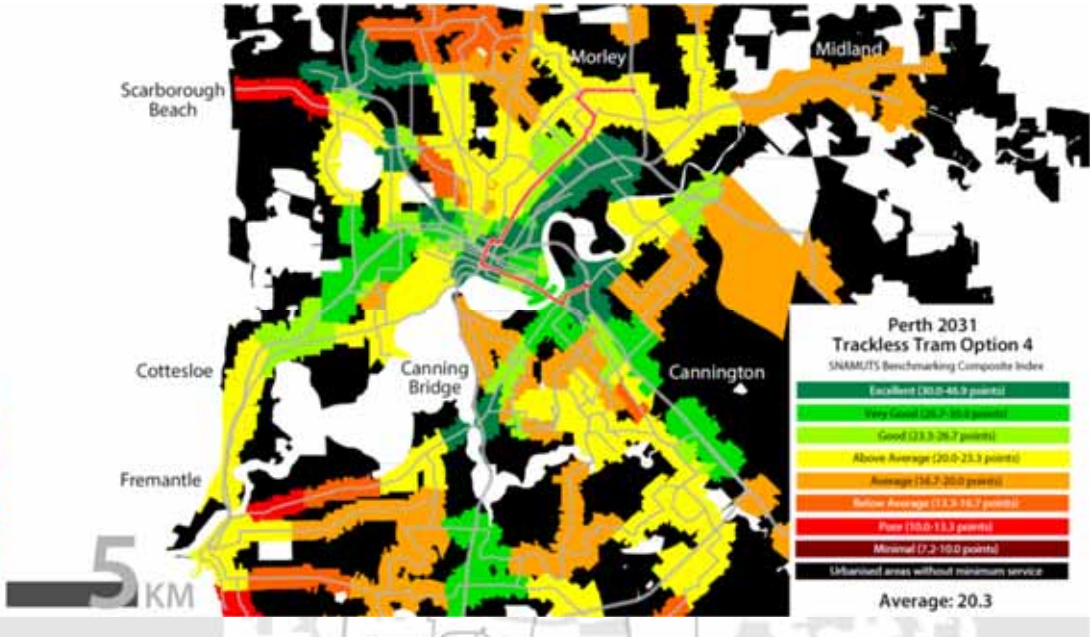


2031 base

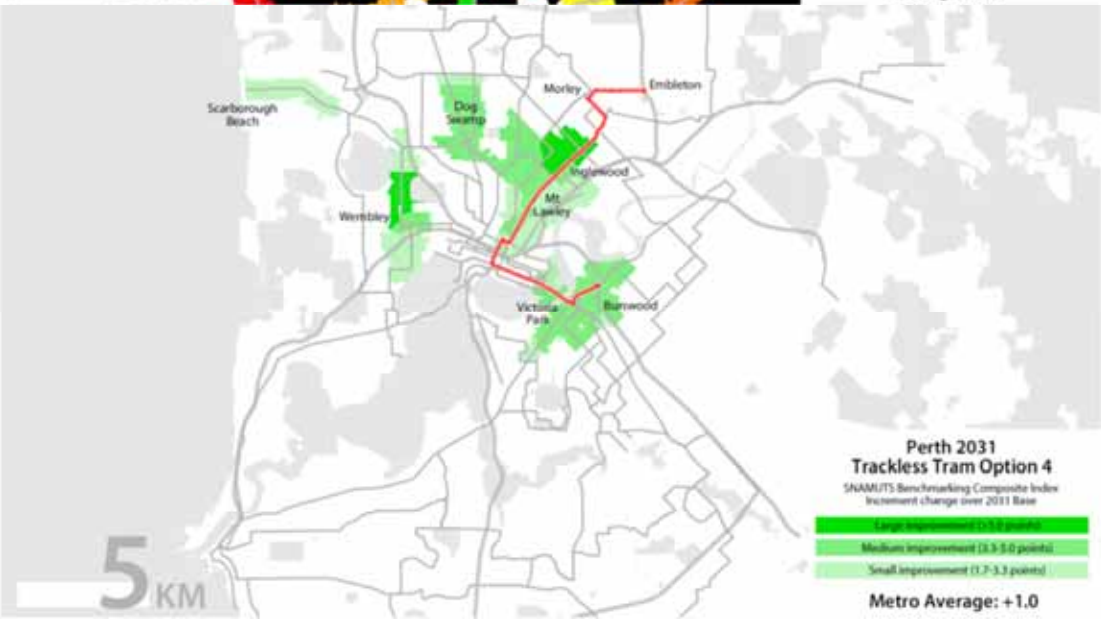
option 3
+
land use

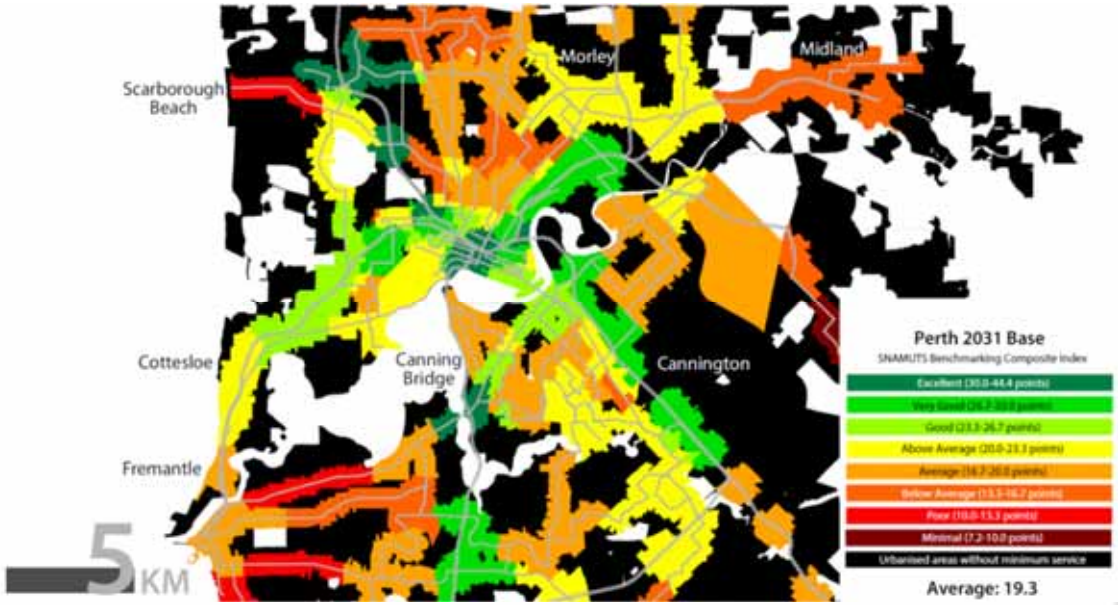


2031 base

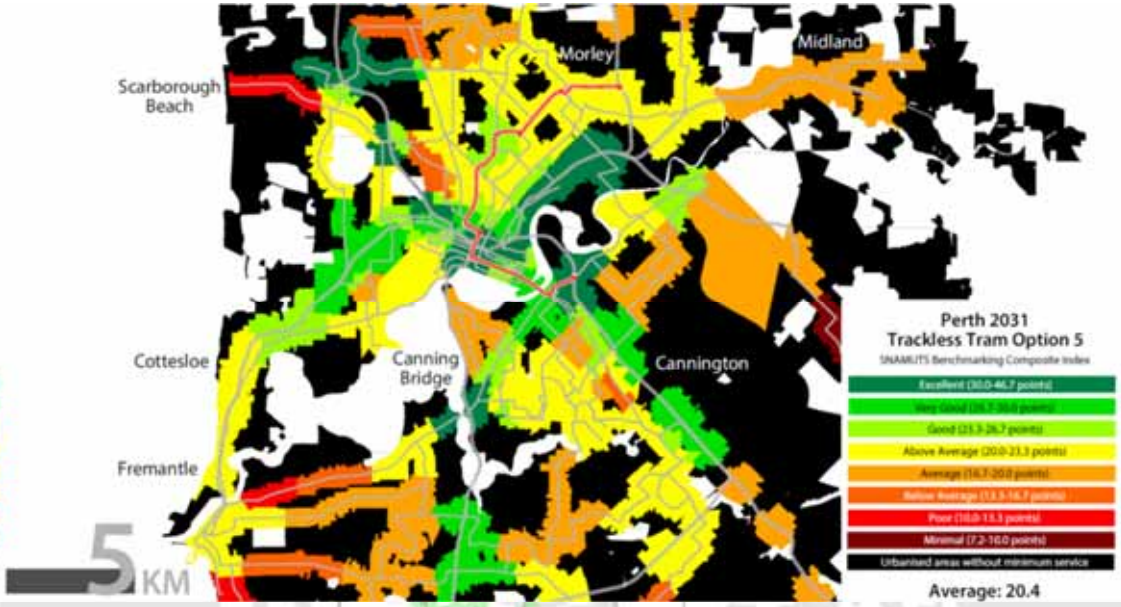


option 4
+
land use

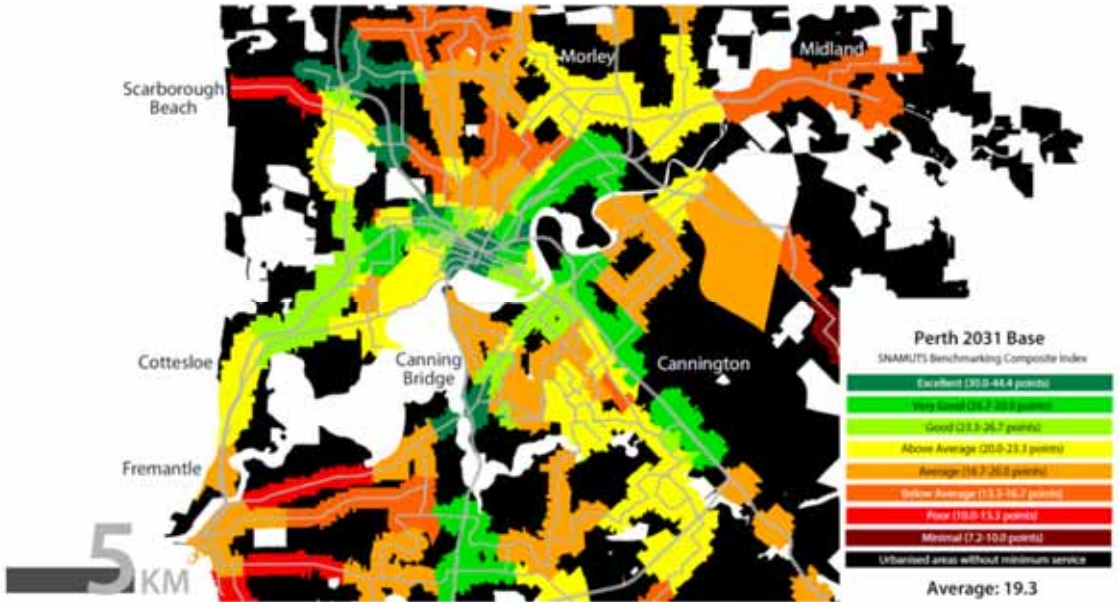




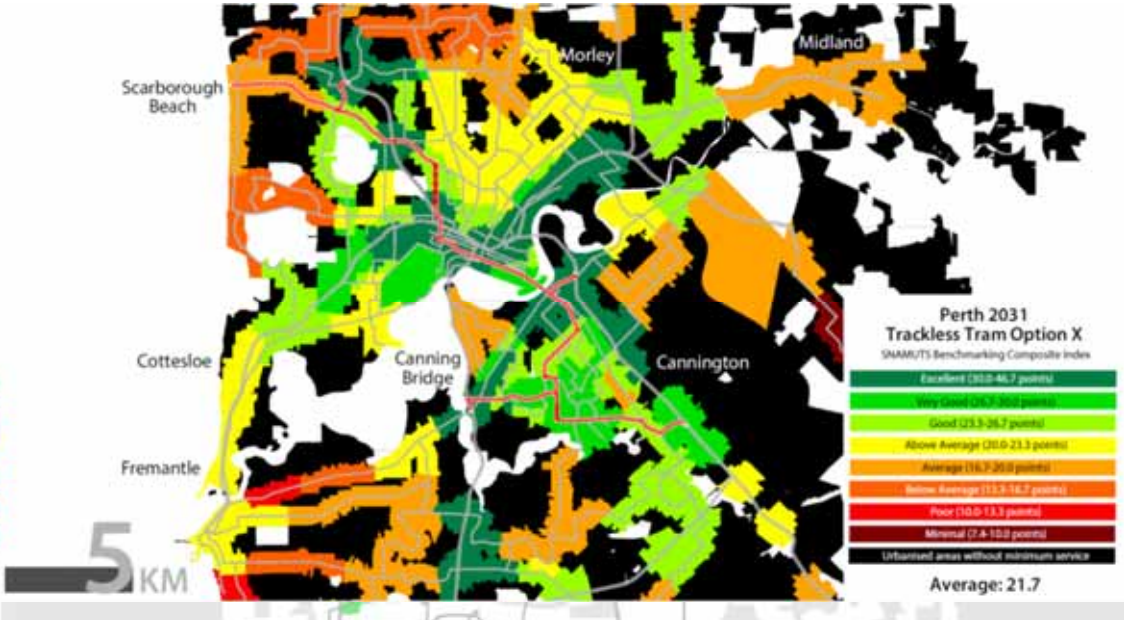
2031 base



option 5
+
land use



2031 base



option x
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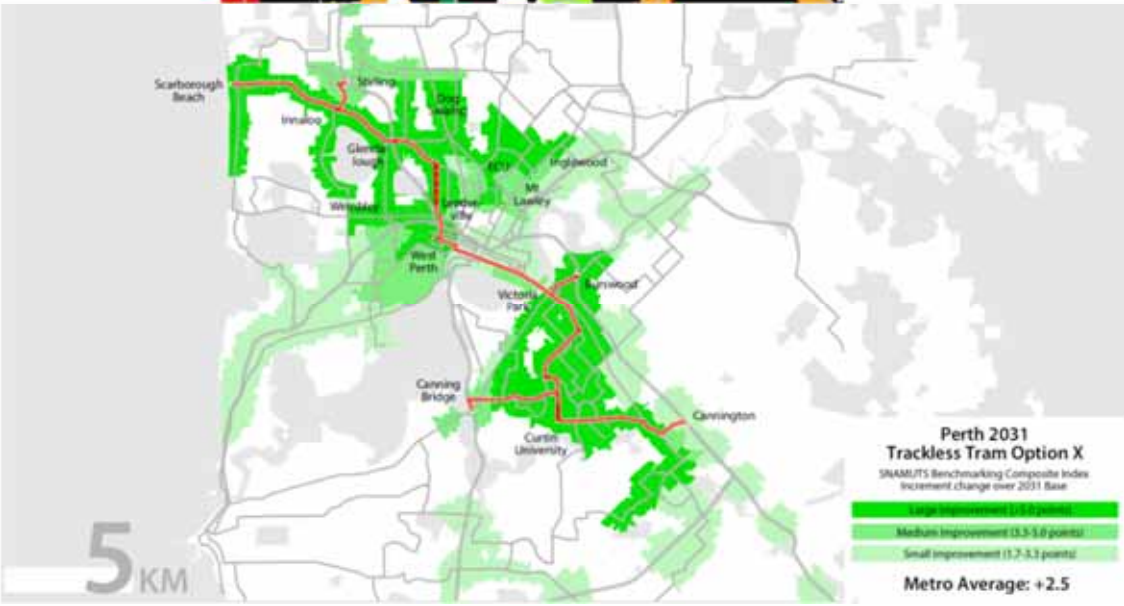
land use



Source: MacroPlanDimasi