
Bus Network Proposal and Analysis

Narre Warren | Fountain Gate

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59 pages

October 2016

executive summary

This paper outlines the rationale and detail of a new bus network in Narre Warren, Melbourne. It proposes a redesigned bus network based on the Triangle Town concept advocated by Bell (2015). This provides a superior network with improved bus-train coordination and more direct services. It is considered that the principal barrier to achieving broader goals of sustainable transport is the lack of integrated land use planning, which is also discussed in this paper. Overall, the proposed changes constitute a significant improvement over existing conditions.

Note: a website has been developed to accompany this paper, primarily to show graphics at a higher resolution. It may be accessed here: <http://jellybean.pw/narrewarrenbusproject>



purpose

The scope and purpose of this paper is to evaluate the existing metropolitan bus system in the suburb of Narre Warren, located 38 kilometres south-east of Melbourne's CBD (profile.id, 2016), and propose an improved network. More detailed analysis of existing conditions and justifications for the new proposal will also be undertaken. The study area, as outlined in Section 3 below, is limited to the suburb boundaries of Narre Warren. Resource and time constraints prevent work beyond these borders.

■ Study Area

The study area for the purposes of this paper is limited to the statistical suburb boundaries for Narre Warren as defined by the Australian Bureau of Statistics (2016).

Figure 1 - Location of Narre Warren (in orange) (OpenStreetMap, 2016)

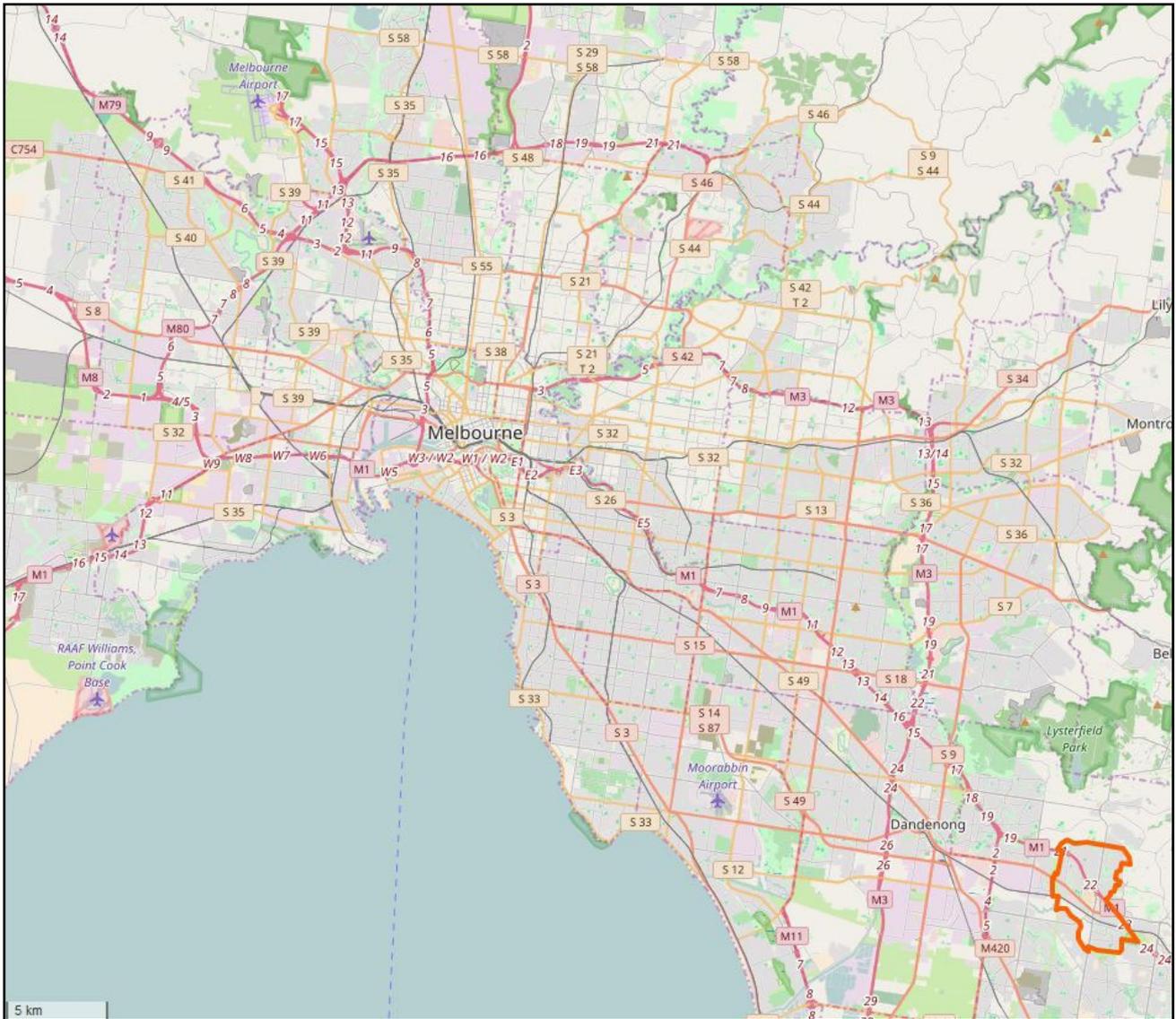
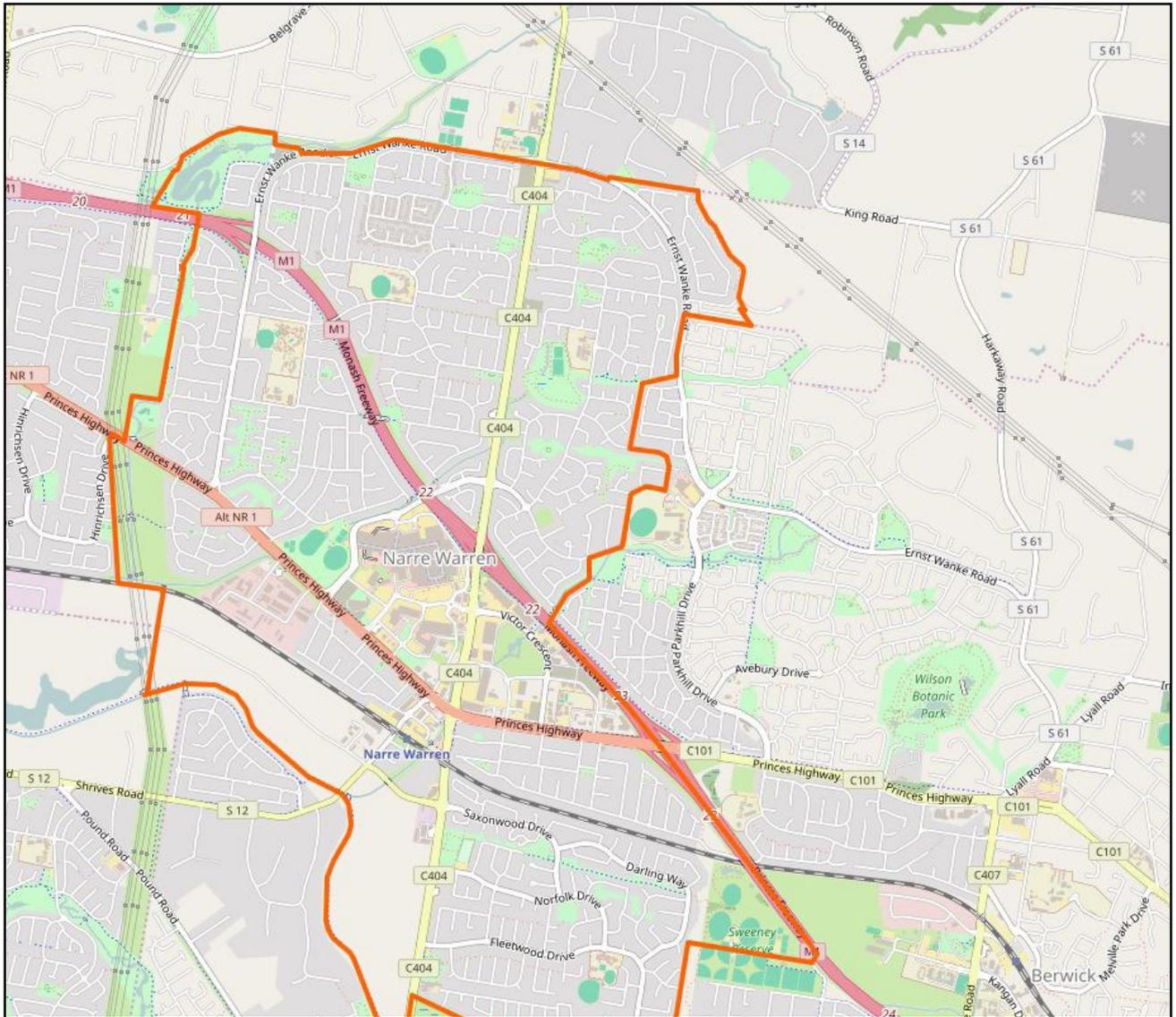


Figure 2 - Map of Narre Warren study area (orange) (OpenStreetMap, 2016)



■ Community Profile

Narre Warren is a growth suburb on the south-eastern edge of Melbourne with a population of approximately 27,220 people (ABS, 2015). While its first development can be traced back to the late 19th century, the first major increases in population are recorded in the late 1980s when the first wave of residential expansion occurred.

The population continued to increase through the 1990s until it plateaued out as development moved further into adjoining suburbs (Monash University, 2015).

The suburb has a number of key demographic characteristics as outlined below in Figures 3 to 8. Some particular points of interest include the relatively young population, the low proportion of people born overseas and the high level of car usage (associated with a miniscule usage of buses).

Figure 3 - Age structure of Narre Warren (ABS, 2011)

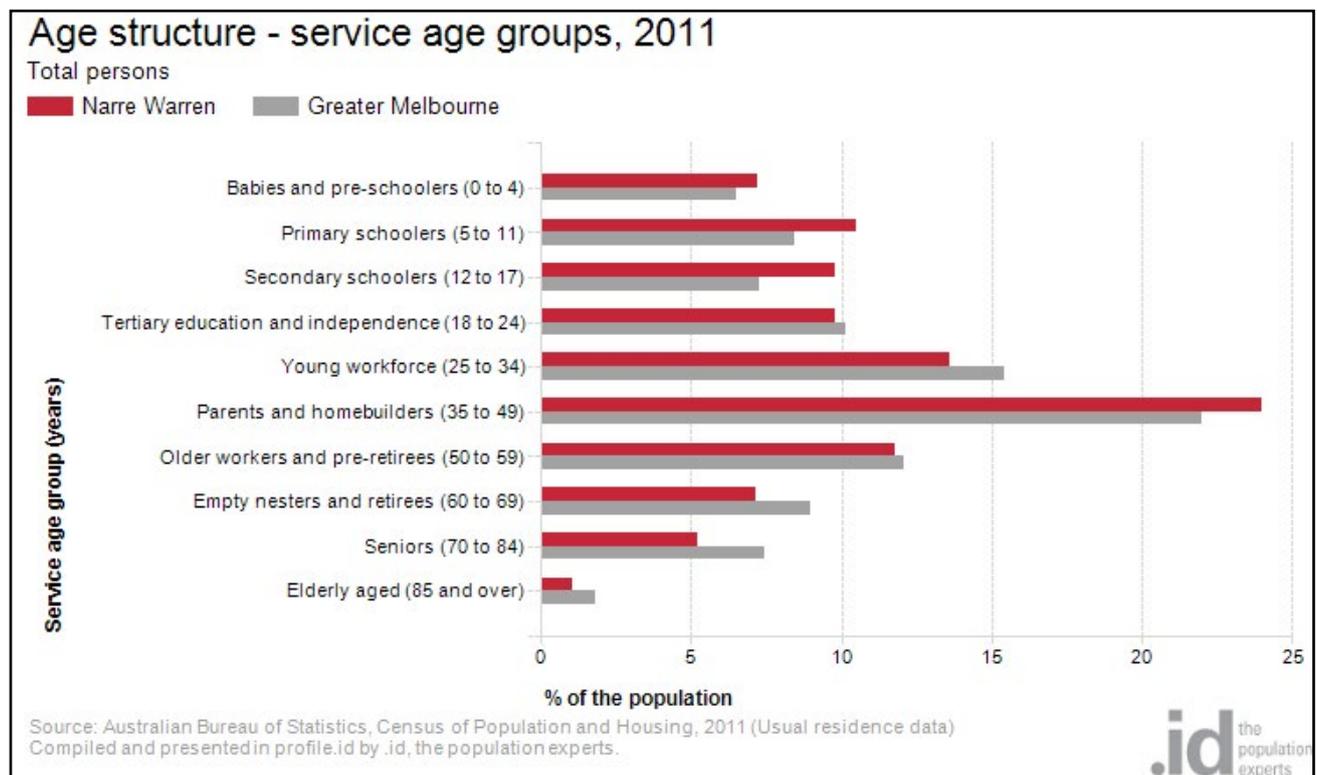


Figure 4 - Birthplace of Narre Warren residents (ABS, 2011)

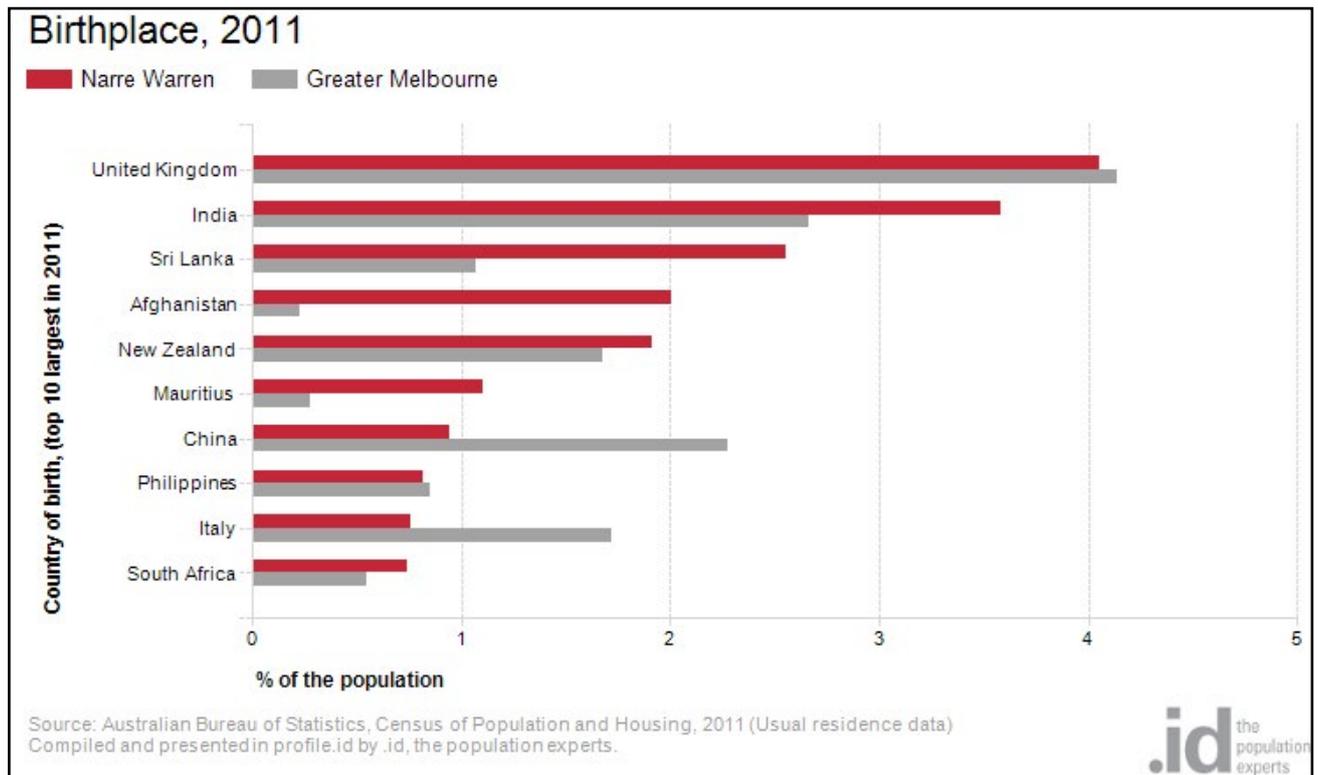


Figure 5 – Car ownership per household of Narre Warren (ABS, 2011)

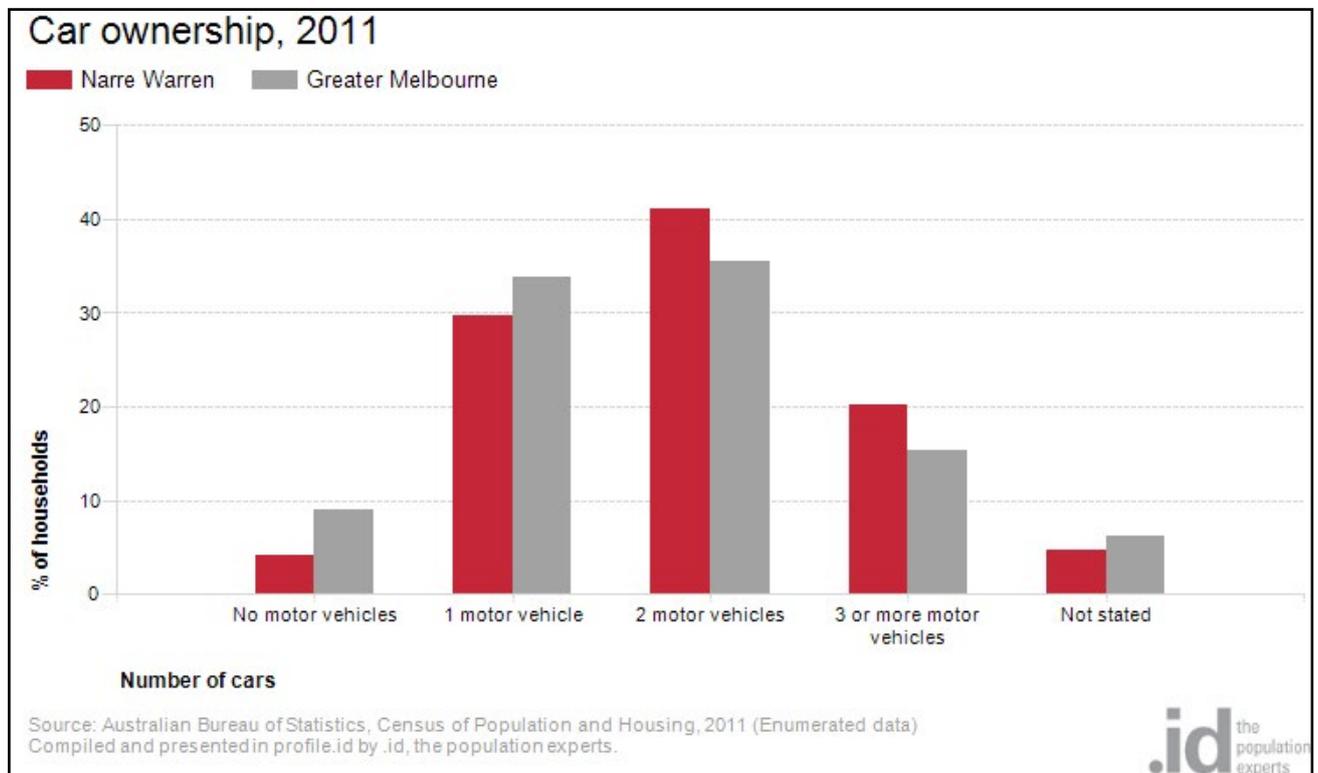


Figure 6 - Method of travel to work per person for Narre Warren (ABS, 2011)

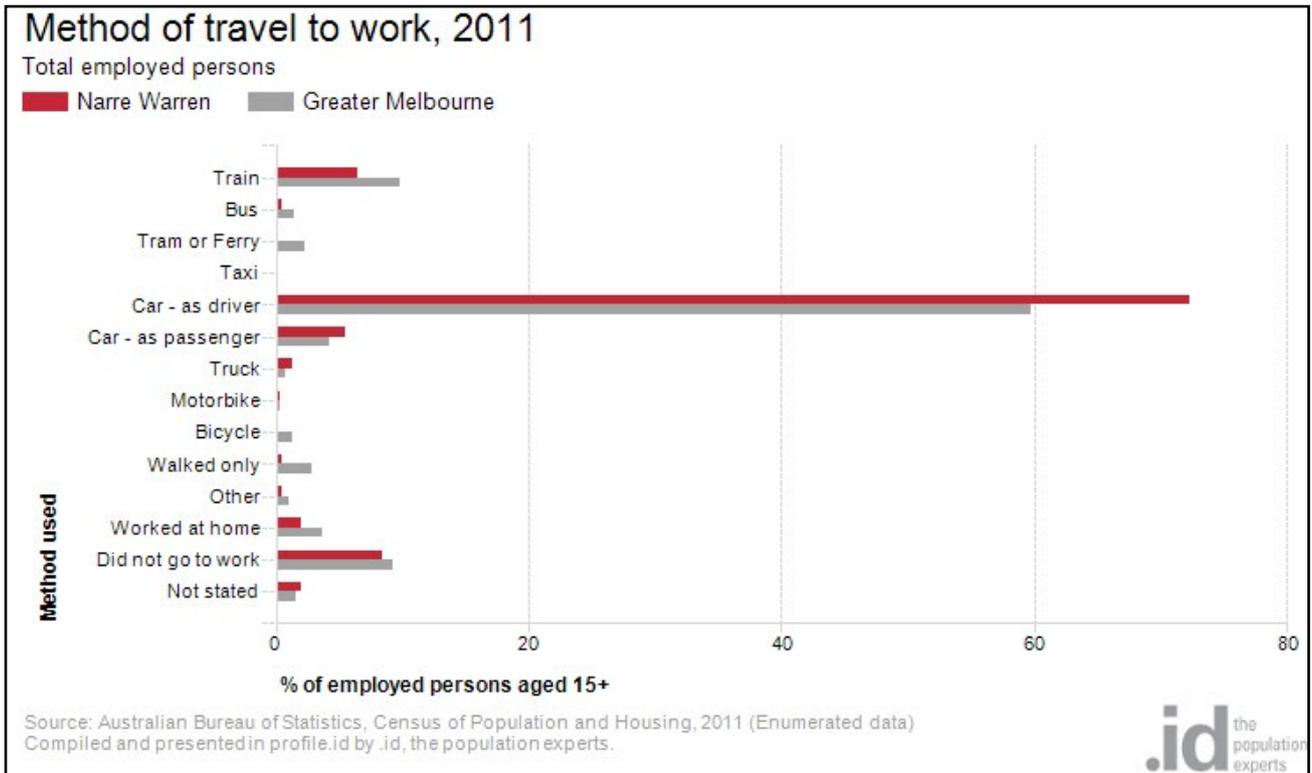


Figure 7 - Place of work of Narre Warren residents (ABS, 2011)

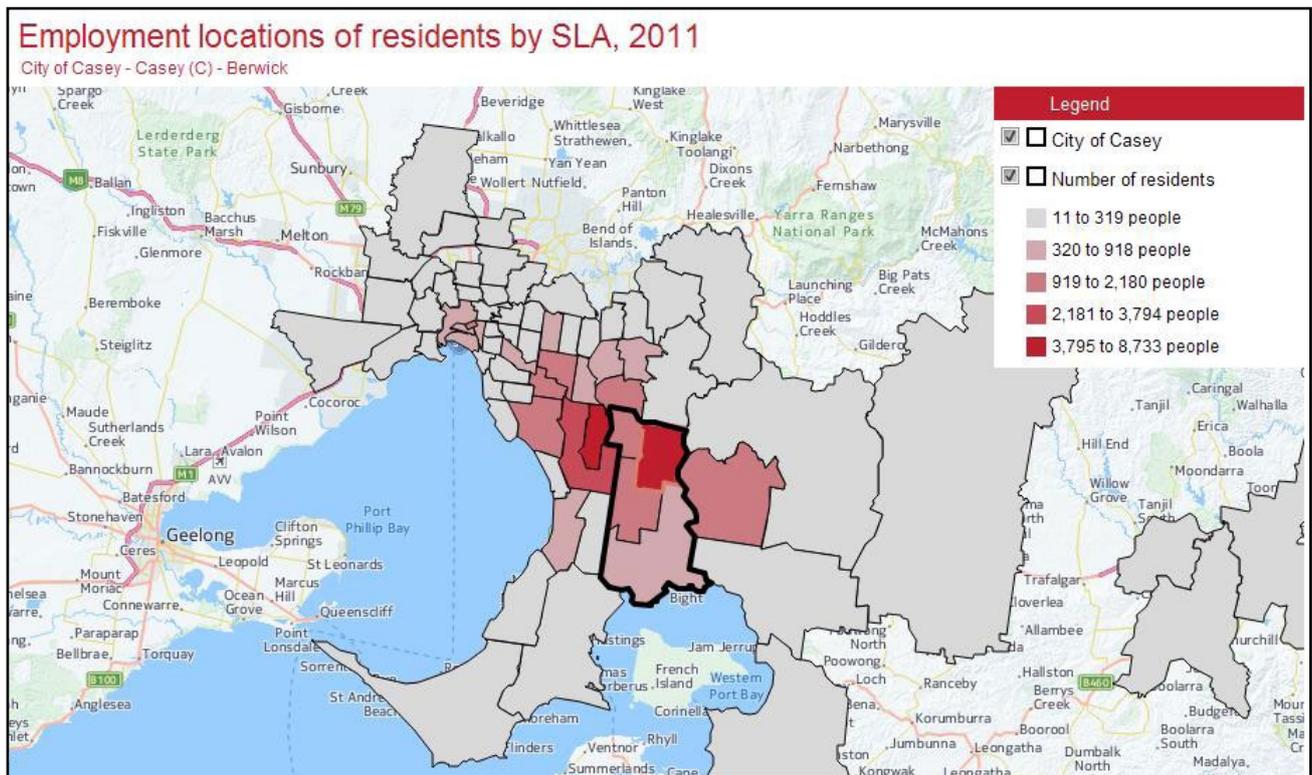
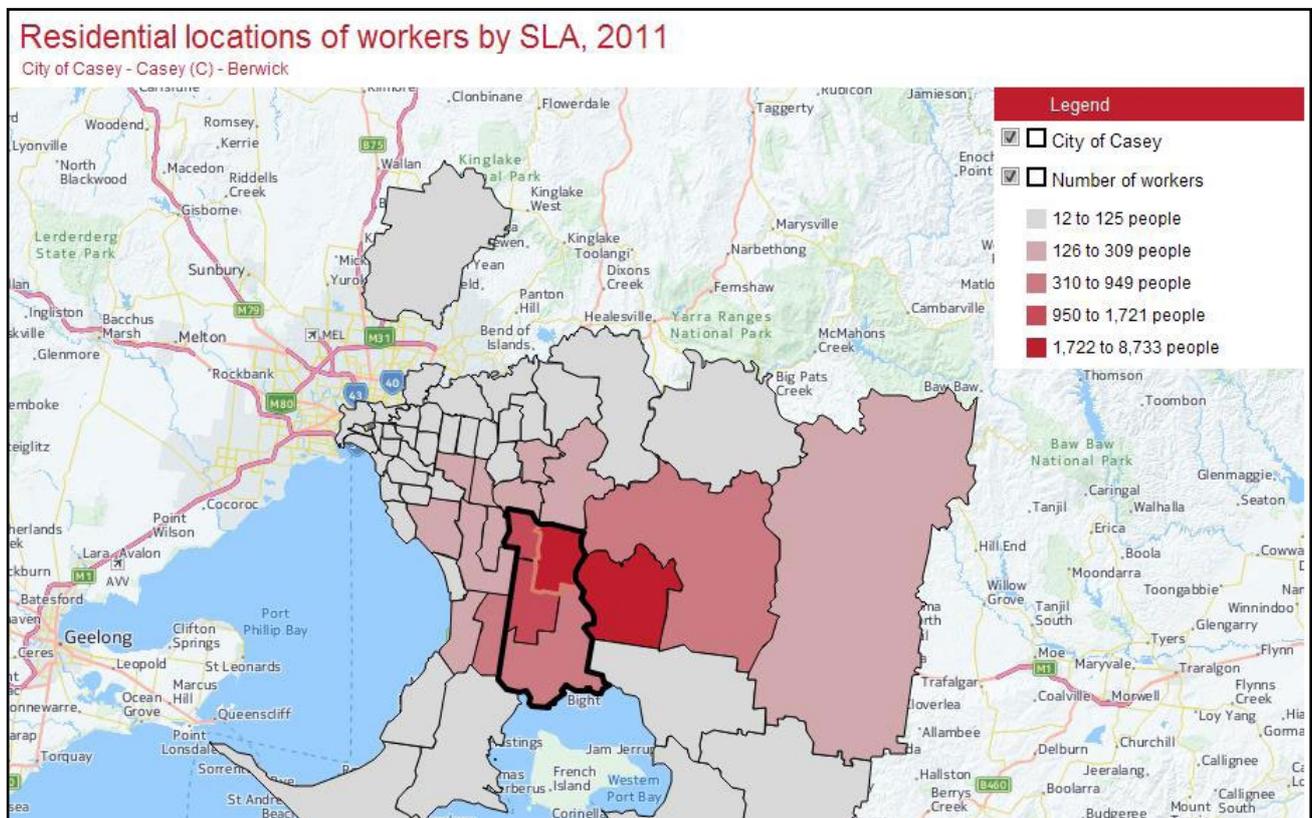


Figure 8 - Place of work of Narre Warren residents (ABS, 2011)



One final point to note in the final two figures (Figures 7 and 8) is that the majority of residents work within or just to the east of the City of Casey. This suggests that residents are not necessarily travelling into the Central Business District of Melbourne for work, but rather travel within the sub-region instead.

Figure 8 also suggests that the majority of workers in Narre Warren are either from the suburb itself or from neighbouring suburbs, primarily in the east. This also promotes a sub-regional or regional approach to transport that would be more suitable for the area.

sustainable transport

'Sustainable transport' has become a catch-all title for the two concepts of public and active transport. The former generally involves the movement of people en masse in the same vehicle while the latter relies on humans moving under their own power (BITRE, 2009). Both are equally important for the ongoing systemic attempts to transition cities to a sustainable existence.

At present, transport contributes around a quarter of global carbon dioxide emissions (Lindsay, et al., 2011). Emissions from transport in Australia are also predicted to continue rising under a 'business as usual' scenario (BITRE, 2009). Other pollutants emitted by transport-related activities also account for tens of thousands of premature deaths every year through direct and indirect health impacts (Woodcock, et al., 2009). It is therefore imperative that sustainable transport modes be prioritised; not only in terms of human health and the environment, but also for the betterment of cities more generally. The negative impacts of cars on cities is well-documented in Australia and around the world, ranging from inefficient use of space to entrenching and creating social inequality.

■ Public Transport Network Approaches

The work of Mees (2000) and Bell (2015) has created two options for network design termed 'Squaresville' and 'Triangle Town' respectively.

SQUARESVILLE

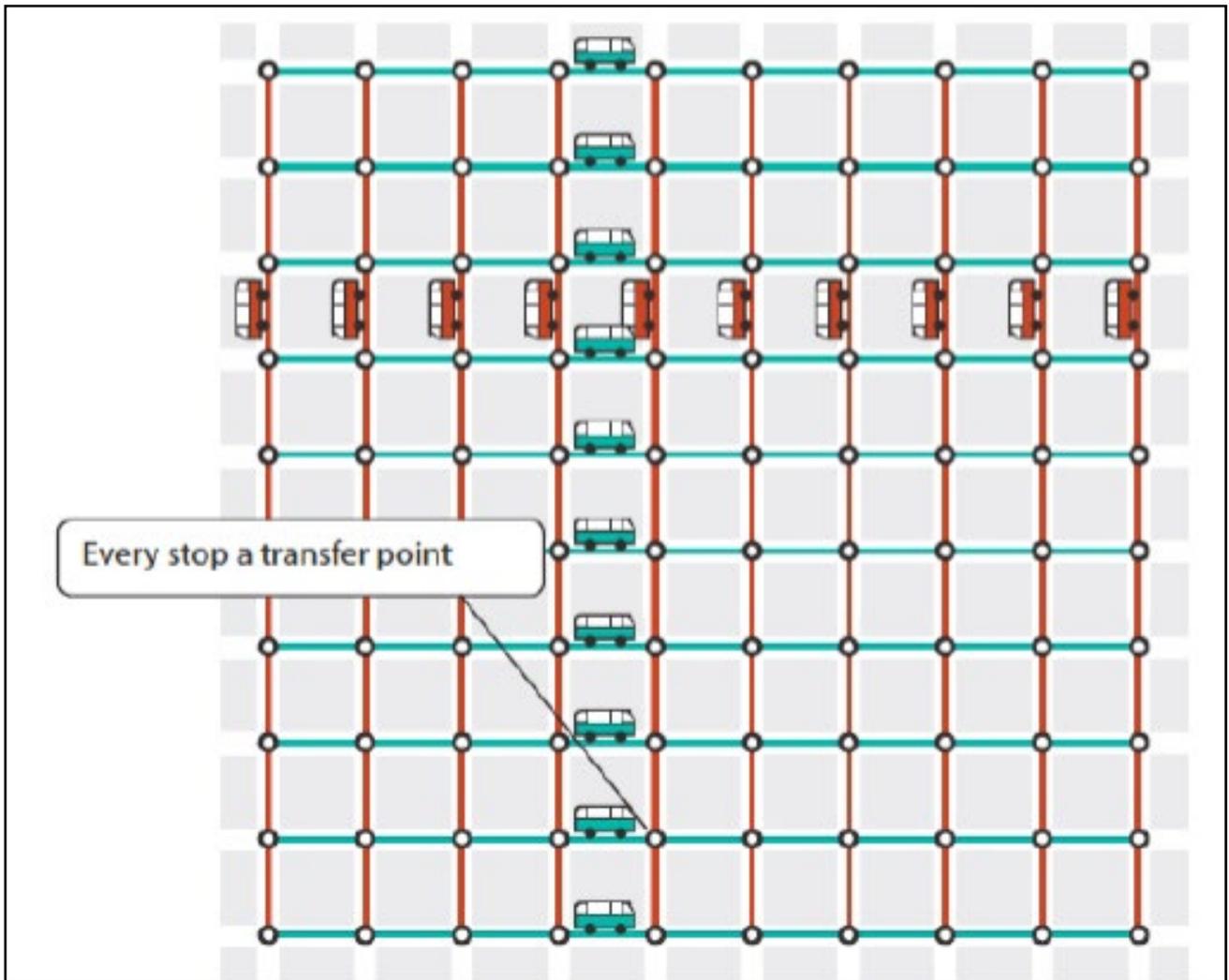
This concept relies on direct, stable, and high-frequency lines intersecting with each other and creating high-quality interchange points as demonstrated in Figure 9 below. This creates what is known as the 'network effect' which is able to service a large number of trips with minimal resources (Mees, 2000).

Mees, et al. (2010) and Nielsen (2005) put forward four key elements for creating the network effect as shown below in Table 2.

Table 2 - Creating a network effect (Mees, et al., 2010; Nielsen, et al., 2005)

Element	Description
Simple line structure	Lines are direct and easy to understand.
Stable line and operating patterns	Network has consistent service levels.
Convenient transfers	High frequencies or coordinated timetables, appropriate infrastructure and good physical locations facilitate easy interchanges.
Appropriate institutions and fare systems	Fare systems encourage transfers and an institutional structure is in place that can adequately coordinate and manage the network.

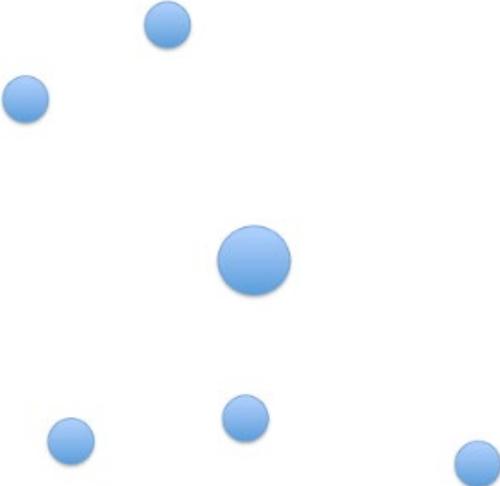
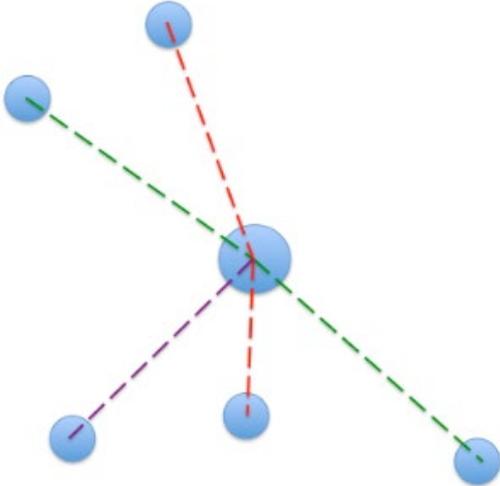
Figure 9 - 'Squaresville' concept in an ideal scenario (Mees, et al., 2010)



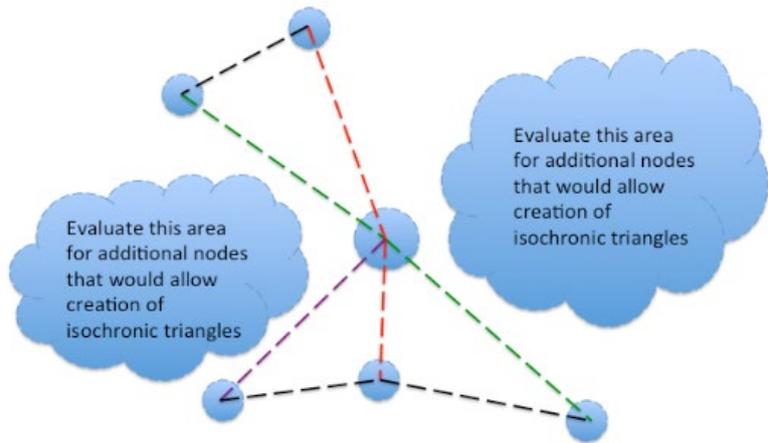
TRIANGLE TOWN

The latter concept was developed in response to Squaresville and borrows ideas from the highly successful public transport network in Zurich, Switzerland (Bell, 2015). This relies on designating nodes within the transport network and connecting them using lines based on triangular geometries. The steps proposed by Bell (2015) are outlined below in Table 3.

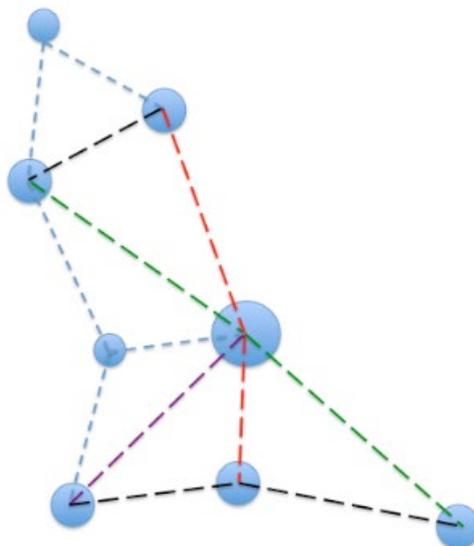
Table 3 - Steps for creating a Triangle Town-based network (Bell, 2015)

Step	Diagram
1) Select nodes	
2) Connect key nodes by using diametric lines through a central node	

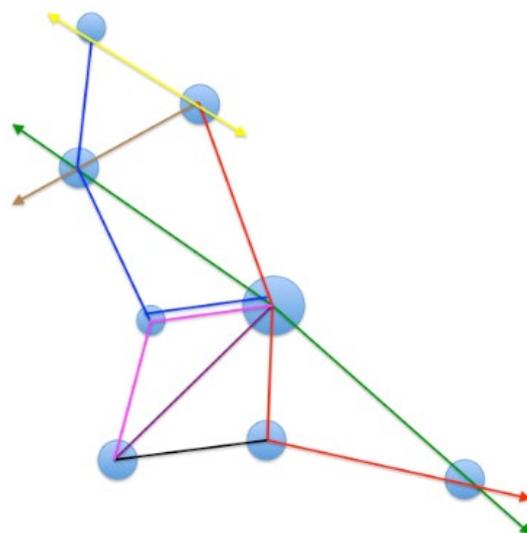
3) Connect key nodes using tangential links



4) Connect additional nodes to the network



5) Design lines to service the triangular backbone



network proposal

This section articulates the new network proposal and rationale for any changes. The first part will use the Triangle Town framework to redesign the line structure of the bus network, with the second part developing new timetables based on this network proposal. Finally, a summary of the changes will be presented in this section's conclusion.

Based on Nielsen et al.'s (2005) contention that a network should have defined goals, as shown in Table 1, it is considered that this network proposal has the following main goals:

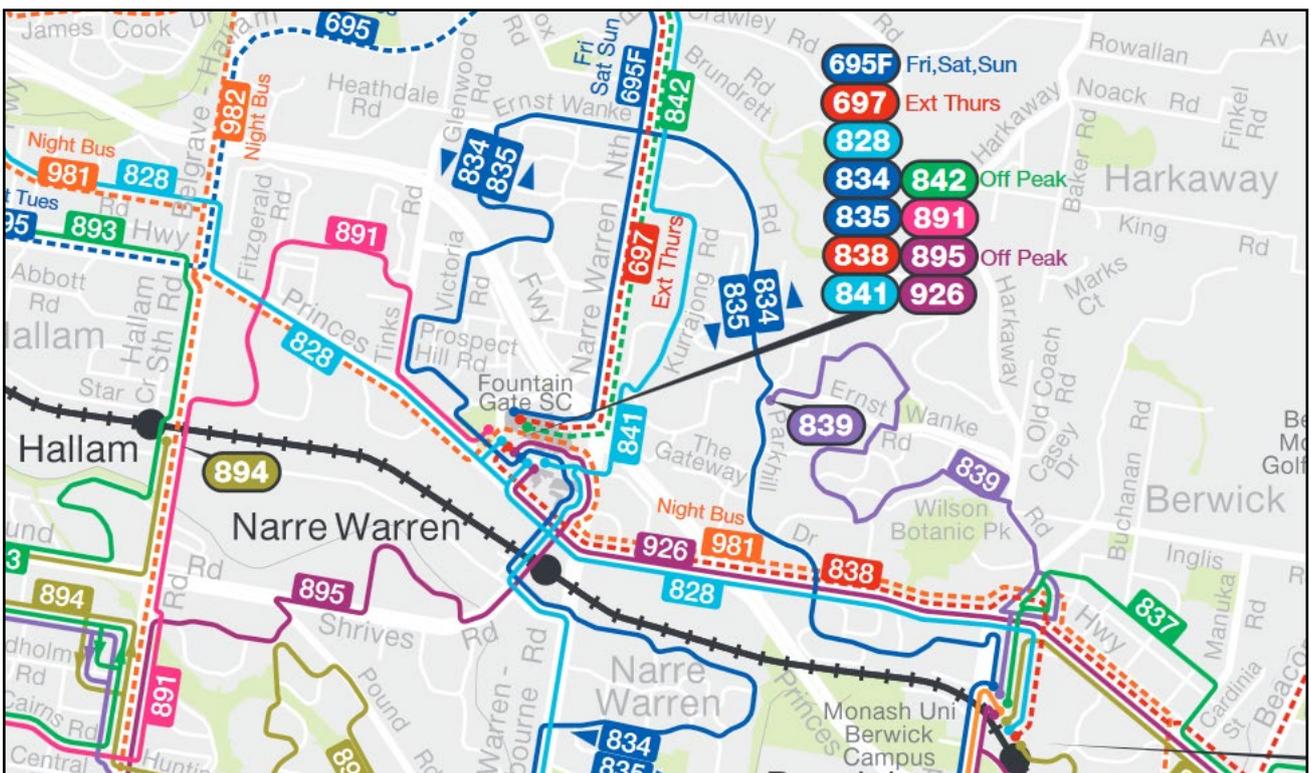
- Provide efficient transport; and
- Contribute to a sustainable city.

These goals guide the development of the new bus network proposal outlined below.

Existing Bus System

The existing system of buses in Narre Warren is unsatisfactory for a number of reasons. It fails to meet many network planning stipulated by Nielsen et al. (2005) and does not coordinate with train arrivals and departures at Narre Warren Railway Station. Many lines have deviations in their route or only run on certain days, while others follow long and indirect routes that preclude competing with cars as a reasonably direct and convenient transport mode. Figure 10 below shows the existing routes for Narre Warren.

Figure 10 - Map of current bus system in Narre Warren (Public Transport Victoria, 2016a)



■ Lines

PROCESS

Based on the study site's spaghetti-like road network and lack of street permeability, Triangle Town is considered the most suitable network design framework for the purposes of this paper, as outlined earlier.

Key nodes within the study area have been selected based on the following attributes:

- Commercial activity
- Education facilities
- Community facilities

These have then been divided into primary and secondary nodes, depending on their strategic importance and likely trip generation. This has resulted in the following nodes being designated in Table 4 below.

Table 4 - Node designation and organisation

Name	Category	Designation
Fountain Gate Shopping Centre	Commercial	Primary
Narre Warren Railway Station	Transport	Primary
Berwick North Shopping Centre	Commercial	Primary
Fountain Gate Secondary College/Primary School	Education	Primary
Marama Primary School	Education	Secondary
Mary MacKillop Primary School (and future Coles site)	Education	Secondary
Oatlands Primary School	Education	Secondary
Don Bosco Catholic Primary School	Education	Secondary

Appendices B-F demonstrate the entire process visually, following the five key steps stipulated in the Triangle Town framework examined earlier in this paper.

PROPOSAL

Having followed the process above, Figure 11 shows a detailed map of the proposed line structure of the new network. Figure 12 and Appendix G show schematic maps of the new network.

Figure 11- Geographical map of proposed new network

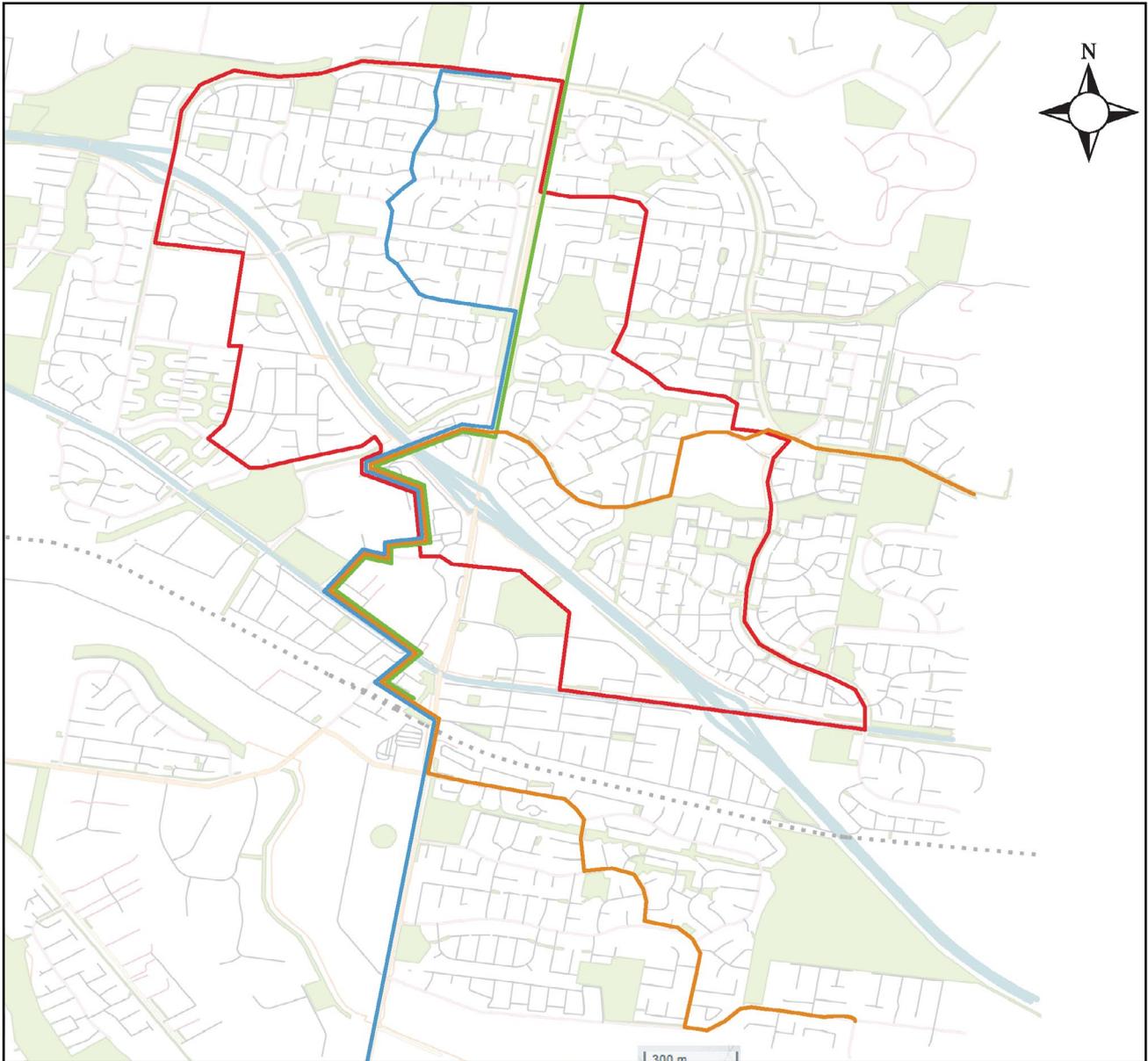
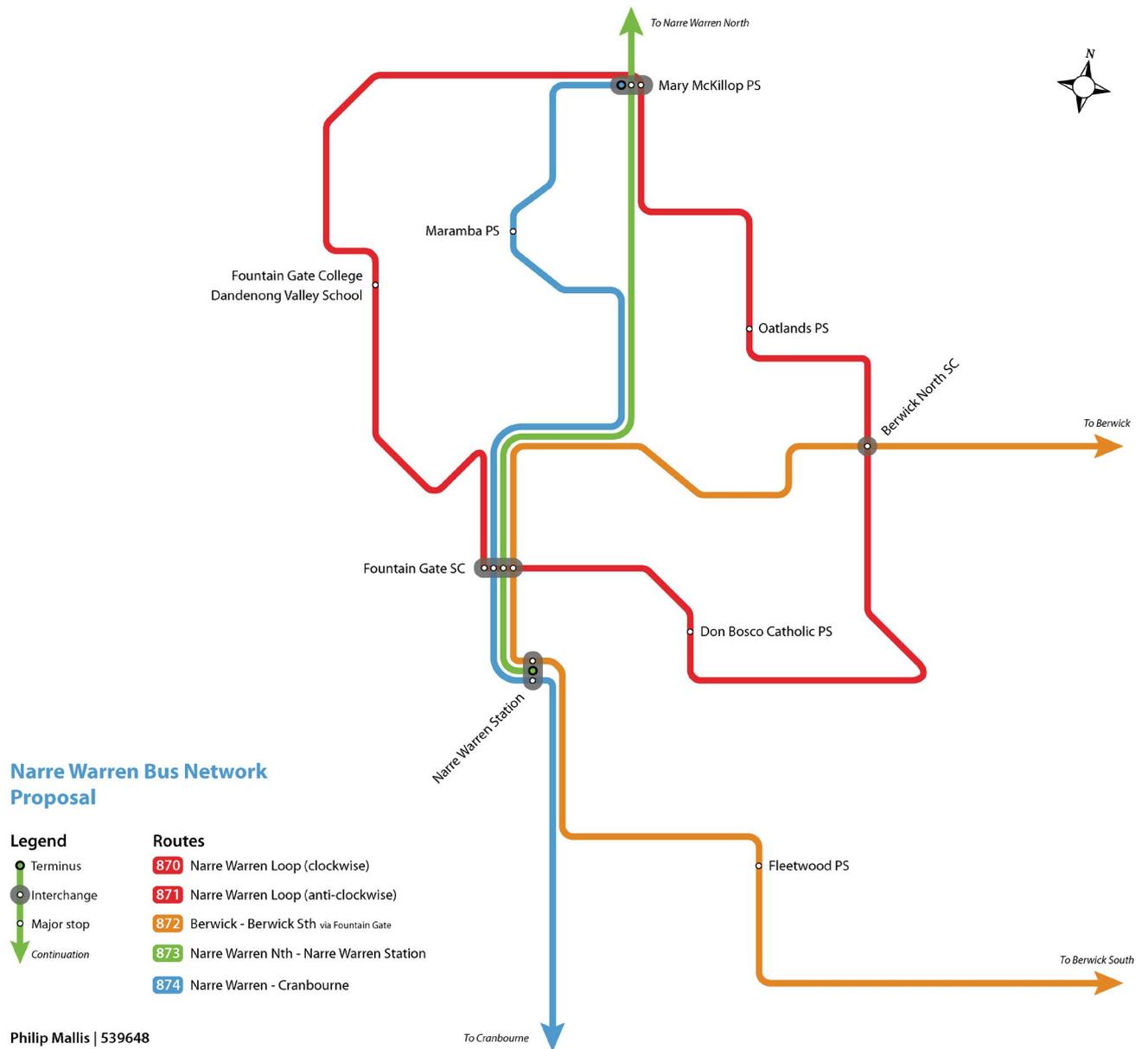


Figure 12 - Schematic map of proposed new network



Note: A higher quality map is available on the project website (working link): <http://jellybean.pw/narrewarrenbusproject>

LIMITATIONS

This proposal faces a number of limitations and confounding factors that prevent a full implementation of the Triangle Town concept.

The principle issue is street connectivity. There are a number of instances across the study area where connections between areas are not possible due to the unavailability of a thoroughfare. This is most evident when examining Figure 11, particularly in the south-east corner of the area. Here there are no crossing points along a 1.5 kilometre stretch of the railway between Narre Warren Road to the west and the Princess Freeway to the east. This has prevented a direct connection across this barrier. Another limitation of this network design is the limited scope of this project.

While there are undoubtedly underserved areas just outside the study boundaries, these areas may not be serviced under the current plan. To address this issue, a more wide-ranging and comprehensive regional or metropolitan-wide study will be necessary, as recently suggested by Infrastructure Victoria (2016).

■ Timetables

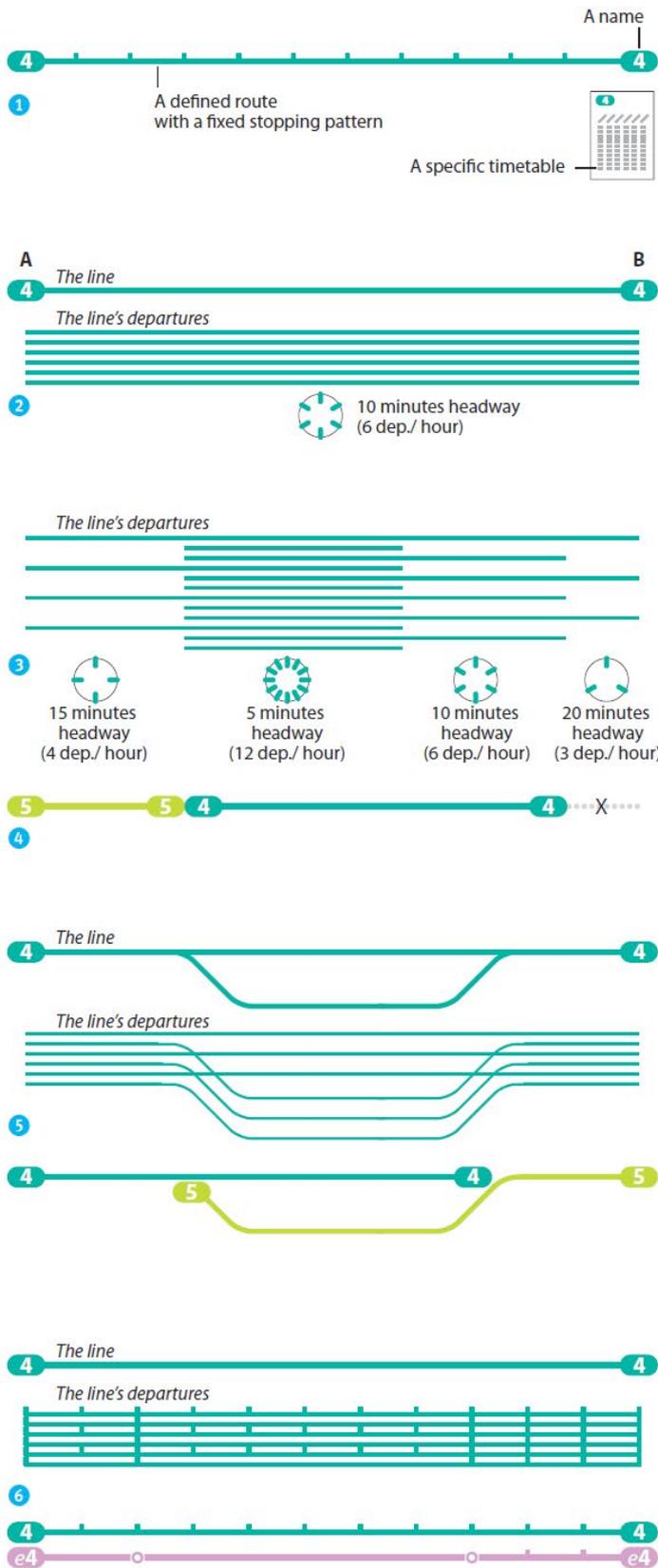
PROCESS

Following the guidance of Nielsen et al. (2005), a structured process incorporating elements from this best practice guide has been followed to develop timetables for the proposed new network. It is proposed to work within existing resources to make the political and institutional implementation of this plan more palatable.

The primary aspect to consider in the context of Narre Warren is coordination with rail services along the Pakenham Line at Narre Warren Station. Although buses should also be considered as creating a public transport network in their own right (Mees, et al., 2010), their function as feeder services to railway stations should not be overlooked, especially during times of low train service frequency. This is to ensure that transfers between modes and services are as seamless and easy as possible which is one of the key aspects of a network proposed by Mees et al. (2010).

Other aspects to consider are outlined by Nielsen et al. (2005), as shown in Figure 13 below.

Figure 13 - Best practice in public transport line design (Nielsen, et al., 2005)



Properties of public transport lines

The line is the basic building element of the public transport network. Name, route, stopping pattern and timetables must be published in various forms. The line is the key to clear and concise information about what the public transport system can offer to the user, as well as the basis for operational planning of the service.

1 The line should have a name. The line should follow a defined route and have a fixed stopping pattern. The departures on the line should be according to a specific timetable.

2 **The ideal line** runs between A and B and all departures follow the same route and stopping pattern. In this example the departures on the line have a frequency of 6 departures per hour, with a 10 minute headway between departures.

3 **A line may have** different frequencies on different sections. This allows for the adjustment of capacity to varying demand along the line, without having to adjust or redesign the line geography.

4 If the market base along the route varies considerably, it will be better to divide the line into separate lines. Then the lines may be run by different types of vehicles resulting in more efficient use of capacity. Each line will then also have its own timetable, so that a section of the route may be without any service at certain periods.

5 **A line should not** follow different routes at different times or departures. The line becomes diffuse, difficult to understand by the public and difficult to inform about. Instead one should create more lines, for instance as illustrated here.

6 **A line should not** have different stopping patterns on different departures. The line concept loses its meaning, the service becomes difficult to understand. Instead one should create more lines with different stopping patterns. For instance, as illustrated here, line 4 is a full-stopping bus line serving all stops along the route. Line e4 is an express bus service with limited stops on the route.

Nielsen et al. (2005) also propose utilising frequencies on the same line as a replacement for the current practice in Narre Warren of altering line geographies to cater for flexible demand during different time periods.

Based on these factors, a framework has been created to guide the development and implementation of the new timetable proposal, partially based on the principles from Nielsen et al. (2005) in Figure 13 above.

This new strategic framework to provide guidance for the creation of new bus timetables is summarised in Table 5 below.

Table 5 - Strategic framework guiding the creation of new bus timetables

Principle	Target
Alignment with rail services	1.1 – every train arriving at or departing from Narre Warren Railway Station will be met by at least one outbound bus and one inbound bus within five minutes of arriving or departing between the hours of 5am and 1am on weekdays and weekends
Comprehensive hours of operation	2.1 – all bus services shall operate with the first service beginning no later than 4:30am and the last service terminating no earlier than 1:00am
Consistency of service	3.1 – no geographical deviations will occur on any line 3.2 – where possible, headways shall be spaced evenly based on a clockface timetable 3.3 – no distinction will be made between Saturday and Sunday services, with a single ‘weekend’ timetable to operate instead
Efficient use of resources	4.1 – no additional service kilometres will be required to operate the new network compared to the existing system

PROPOSAL

The timetable proposal is based on the three key principles summarised in Table 5 in the previous section. The timetable proposal, an example of which may be found at Figure 14 and on the project website, will be assessed against these three principles, outlined in Table 6 below.

Table 6 - Strategic framework guiding creation of new bus timetables

Target	Met?	Assessment
1.1 – every train arriving at or departing from Narre Warren Railway Station will be met by at least one outbound bus and one inbound bus within five minutes of arriving or departing, between the hours of 5am and 1am on weekdays and weekends		However, Target 1.1 is met, with every train being met by at least one bus at all times between 5am and 1am. In most instances, two or more buses in different directions and servicing different lines.
2.1 – all bus services shall operate with the first service beginning no later than 4:30am and the last service terminating no earlier than 1:00am		All services exceed Target 2.1 with the last service on all routes terminating after 1:00am. It is considered that night trains arriving after this time on Fridays and Saturdays are serviced by the separate Night Bus system (Public Transport Victoria, 2016b).
3.1 – no geographical deviations will occur on any line		The new network does not propose any geographical deviations on any route.
3.2 – where possible, headways shall be spaced evenly based on a clockface timetable		Due to the scope of this project, it has not been possible to alter the timetable to provide departures and arrivals based on a clockface timetable. The current train timetable has irregular times throughout the day, except for the period between approximately 8:00am and 5:00pm. This has necessitated irregular times in the timetables of the new bus routes that service the station (872, 873 and 874). While Target 3.2 has been achieved across most timetables, it has not been possible to provide clockface headways outside the hours of 8:00am and 5:00pm.

Target	Met?	Assessment
3.3 – no distinction will be made between Saturday and Sunday services, with a single 'weekend' timetable to operate instead	✓	The new network does not propose separate Saturday and Sunday timetables.
4.1 – no additional service kilometres will be required to operate the new network compared to the existing system	✓	The new network does not require additional service kilometres to operate. Far from requiring more resources, there is a surplus of service kilometres and could be transferred to surrounding areas in need of additional resources, or 'saved' for any potential future needs.

Figure 14 below shows the proposed new bus timetable for Narre Warren Railway Station. As seen in Appendix H, every train is met by at least one bus upon arrival. Figures 15 and 16 also demonstrate the current and proposed bus service provision for the study area.

Figure 14 - New timetable proposal for Narre Warren Station: design from Public Transport Victoria (2016)

Note: A higher quality version is available on the project website: <http://jellybean.pw/narrewarrenbusproject>

Ventura
PT >

Narre Warren Station

Route 872	Berwick <small>via Fountain Gate SC</small>	
Route 873	Narre Warren Station <small>via Fountain Gate SC</small>	
Route 874	Cranbourne <small>via Fountain Gate SC</small>	

Route 872	Route 873	Route 874
Monday to Friday		
AM	AM	AM
5 06 46	5 06 46	5 26
6 15 44	6 06 30 53	6 06 30 44 59
7 06 27 44 57	7 13 30 52	7 27 30 57
8 10 30 50	8 12 20 40	8 10 30 50
9 10 30 50	9 00 20 40	9 10 30 50
10 10 30 50	10 00 20 40	10 10 30 50
11 10 30 50	11 00 20 40	11 10 30 50
PM	PM	PM
12 10 30 50	12 00 20 40	12 10 30 50
1 10 30 50	1 00 20 40	1 10 30 50
2 10 30 50	2 00 20 40	2 10 30 50
3 10 30 50	3 00 20 40	3 10 30 50
4 10 30 50	4 00 20 40	4 10 30 50
5 10 30 45	5 00 20 40	5 10 30 45
6 09 23 43	6 16 34 54	6 09 23 43
7 05 25 45 55	7 14 34 59	7 05 25 45 55
8 15 40 55	8 20 37	8 15 40 55
9 20	9 00 40	9 20
10 00 40	10 20 45	10 00 40
11 05	11 10 32	11 05
12 02 32	12 02 32	12 02 32
AM	AM	AM
1 02	1 02	1 02

Proposed timetable only

Service Information

All services are operated by wheelchair accessible vehicles (other than exceptional circumstances)

 (1) Saturday timetable operates on all public holidays except Good Friday and Christmas Day

 (2) Sunday timetable operates on Good Friday and Christmas Day

 All times are subject to alteration without notice.

Customer Information

For more information or to give feedback visit ptv.vic.gov.au or call **1800 800 007**

StopID: 3079; DIVA: 15221
Stop number: 3079
20:10:2016 19:36:52

These times are subject to road and traffic conditions

Figure 15 - Calculation of existing service provision for Narre Warren bus network

Bus - Narre Warren/Fountain Gate					
Weekdays					
Route	Origin	Destination	Length (Km)	Services (No.)	Service Provision
695F	Gembrook	Fountain Gate	6.4	12	76.8
697	Belgrave	Belgrave South	6.4	2	12.8
828	Hampton	Berwick Station	8.8	84	739.2
834	Berwick Station	Narre Warren Circle	27.2	40	1088
835	Berwick Station	Narre Warren Circle	27.2	39	1060.8
838	Emerald	Fountain Gate	4.8	6	28.8
841	Narre Warren North	Cranbourne	15.6	60	936
842	Fountain Gate	Endeavour Hills SC	6.2	6	37.2
891	Lynbrook	Fountain Gate	6.6	49	323.4
895	Narre Warren South	Fountain Gate	4.2	44	184.8
926	Pakenham Station	Fountain Gate	4.8	32	153.6
					4641.4
Saturday					
Route	Origin	Destination	Length	Services	Service Provision
695F	Gembrook	Fountain Gate	6.4	16	102.4
697	Belgrave	Belgrave South	6.4	0	0
828	Hampton	Berwick Station	8.8	30	264
834	Berwick Station	Narre Warren Circle	27.2	18	489.6
835	Berwick Station	Narre Warren Circle	27.2	18	489.6
838	Emerald	Fountain Gate	4.8	0	0
841	Narre Warren North	Cranbourne	15.6	34	530.4
842	Fountain Gate	Endeavour Hills SC	3.1	0	0
891	Lynbrook	Fountain Gate	6.6	28	184.8
895	Narre Warren South	Fountain Gate	4.2	28	117.6
926	Pakenham Station	Fountain Gate	4.8	30	144
					2322.4
Sunday					
Route	Origin	Destination	Length	Services	Service Provision
695F	Gembrook	Fountain Gate	6.4	14	89.6
697	Belgrave	Belgrave South	6.4	0	0
828	Hampton	Berwick Station	8.8	27	237.6
834	Berwick Station	Narre Warren Circle	27.2	13	353.6
835	Berwick Station	Narre Warren Circle	27.2	13	353.6
838	Emerald	Fountain Gate	4.8	0	0
841	Narre Warren North	Cranbourne	15.6	26	405.6
842	Fountain Gate	Endeavour Hills SC	3.1	0	0
891	Lynbrook	Fountain Gate	6.6	26	171.6
895	Narre Warren South	Fountain Gate	4.2	26	109.2
926	Pakenham Station	Fountain Gate	4.8	26	124.8
					1845.6

NOTES: *Length is inbound and outbound*
 Service no. are inbound and outbound

Figure 16 - Calculation of service provision for proposed Narre Warren bus network

Bus - Narre Warren/Fountain Gate						
Weekdays						
Route	Origin	Destination	Length (Km)	Services (No.)	Service Provision	
870	Narre Warren Loop	Clockwise	14.7	60	882	
871	Narre Warren Loop	Anti-clockwise	14.7	60	882	
872	Berwick	Berwick South	8.5	60	510	
873	Narre Warren North	Narre Warren Station	4.5	60	270	
874	Narre Warren	Cranbourne	7.3	60	438	
					2982	
Saturday						
Route	Origin	Destination	Length	Services	Service Provision	
870	Narre Warren Loop	Clockwise	14.7	57	837.9	
871	Narre Warren Loop	Anti-clockwise	14.7	57	837.9	
872	Berwick	Berwick South	8.5	57	484.5	
873	Narre Warren North	Narre Warren Station	4.5	57	256.5	
874	Narre Warren	Cranbourne	7.3	57	416.1	
					2832.9	
Sunday						
Route	Origin	Destination	Length	Services	Service Provision	
870	Narre Warren Loop	Clockwise	14.7	57	837.9	
871	Narre Warren Loop	Anti-clockwise	14.7	57	837.9	
872	Berwick	Berwick South	8.5	57	484.5	
873	Narre Warren North	Narre Warren Station	4.5	57	256.5	
874	Narre Warren	Cranbourne	7.3	57	416.1	
					2832.9	

NOTES: *Length is inbound and outbound*
 Service no. are inbound and outbound

In summary, it is considered that the proposal provides a superior timetable to the current bus network. At present, as outlined earlier in this paper, coordination between the various modes of transport servicing Narre Warren is unsatisfactory. The main advantage of this new timetable is that a bus meets every train arriving or departing from the station within five minutes, ensuring a smooth interchange for passengers between transport modes (see Appendix H. Due to the constraints of the train timetable, this has come at the expense of a consistent clockface timetable. However, the benefits are considered to outweigh any costs in this particular context, given the importance of this intermodal transfer in Narre Warren.



integrated land use

This section will examine land use planning on the context of the Narre Warren study area. The current conditions at the site will be articulated and analysed in the context of the literature review previously outlined in this paper. This will then inform proposals to improve the land use planning arrangements, in order to work towards achieving the goal of a sustainable city.

■ Literature Review

The necessity of integrated planning between transport and land use is well-documented throughout Australian and international literature. This section will briefly summarise key aspects of the available evidence with a view to utilising these resources in the planning and development of a new bus network for Narre Warren. It will also provide a basis upon which to analyse integrated land use planning in particular further in this paper.

METROPOLITAN GOVERNANCE

Australia has traditionally suffered from a lack of integration between urban planning, transport and other aspects of cities. Development has primarily relied on a 'siloed' approach, whereby different entities are responsible for each aspect of a city and rarely, if ever, coordinate or cooperate. Gleeson, et al (2010) refer to this unsatisfactory state of affairs as 'system fragmentation'. While it is true that fragmentation is a significant issue in modern Australia, it is one part of an even wider issue with governance and government. The Classical view of public administration, supported by Wilsonian ideas of bureaucratic structures and activities (Wilson, 1887; Bourgon, 2011), is still very much alive in modern Australia. This is coupled with more contemporary ideas of New Public Management (NPM) which advocate for less government and market-led approaches (Considine & Lewis, 2003; Healey, 2010). Neither of these paradigms offer feasible ways forward for addressing the huge and complex problems of metropolitan governance.

PLANNING AND TRANSPORT INTEGRATION IN MELBOURNE (OR LACK THEREOF)

Much literature has been published on the various aspects of the planning system in Victoria and Melbourne. Many contend that the present system, based on a veritable spider's web of fragmented and confusing responsibilities, is dysfunctional and does not serve the strategic long-term needs of the city (Gleeson, et al., 2010; Lazanas & Stone, 2010; Tomlinson, 2012; Legacy, et al., 2014; Whitzman & Ryan, 2014).

As outlined previously, the overall governance arrangements for Melbourne are quite unsatisfactory for the future development of the city. This is borne out in the example of integrated transport and land use planning in and around the urban centre. The theory of path dependence, whereby "self-reinforcing mechanisms exist in the logic of production to ensure that a type of product prevails on the market even though better alternatives exist" (Low & Astle, 2009). As argued by Low & Astle (2009), the path dependence of institutional arrangements for urban passenger transport have created an environment in Melbourne where private cars are prioritised over sustainable transport modes. This has resulted in strong road institutions, which are arguably much better integrated into land use planning in Victoria, and weakened public transport institutions (Low & Astle, 2009).

Consequently, land use planning has often occurred without any reference to the current or future transport needs of people, beyond private car usage. Sprawling and rapid suburban growth on the urban fringes of Melbourne has resulted in large tracts of land developed with little or no public or active transport infrastructure (Dodson, 2009). This has resulted in suburbs that are car-dependent and lack a strategic focus to implement rational design features that would make these areas sustainable (Rahnam, et al., 2015). Governments at all levels have failed to ensure that land use planning has occurred in concert with transport planning; not simply token gestures made well after the fact.

It is not only governments and other public institutions that have caused or allowed this state of affairs. The conventional wisdom of urban development in Australia favours a neoliberal market-led approach, whereby land is turned over to private developers (Goodman, 2016). This is then developed into a series of separately-built housing estates with little or no collaboration with other entities beyond the statutory planning process (Whitzman & Ryan, 2014).

In summary, the general consensus in the academic literature is for cities to move away from private car usage and firmly towards sustainable transport. By following network planning best practice in conjunction with integrated land use strategies, much can be achieved in Melbourne towards achieving this goal.

■ Current Conditions

As Narre Warren was not planned or built using any implemented strategy or framework, the urban typology is fragmented and uncoordinated. This section will outline the current land use attributes in Narre Warren, beginning with articulating the existing zones in the study area. This will then be examined in light of the location of transport, education and other community facilities.

Narre Warren is dominated by low-density residential development. It features only two retail centres: Fountain Gate Shopping Centre, the second-largest in Australia (Scentre Group, 2016), and Berwick North, a small local retail centre in the north-east of the suburb (see Figures 17 and 18 below).

Figure 17 - Fountain Gate Shopping Centre (Mallis, 2016)



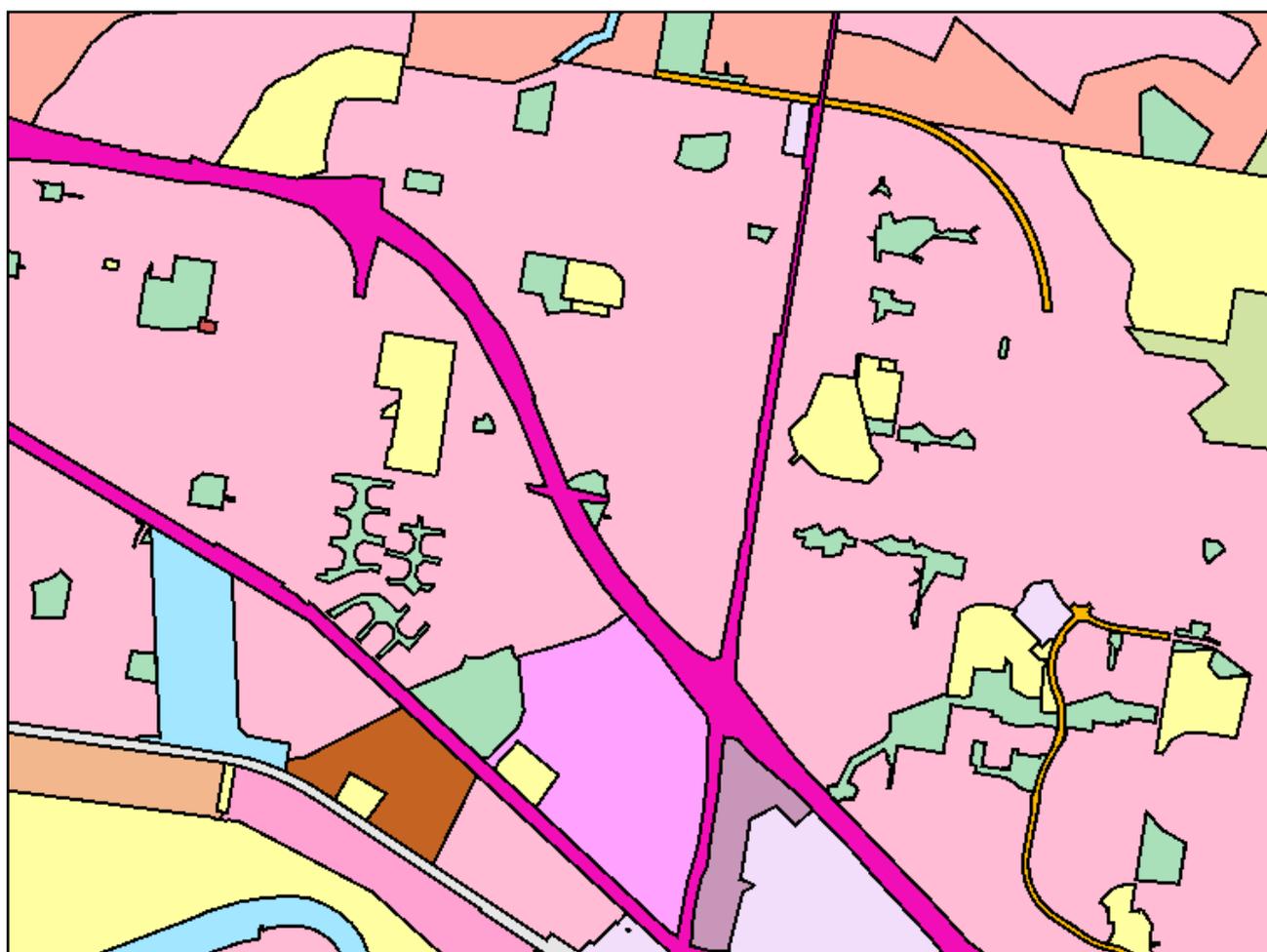
Figure 18 - Berwick North Shopping Centre (Mallis, 2016)



As is evident in both figures, both centres are heavily car-dependent. Fountain Gate alone has over 7,000 car parking spaces under its control, not including other private and public car parks in the vicinity (Scentre Group, 2016).

Even a cursory look at a zoning map of the suburb (Figure 19) also reveals very homogenous zoning throughout the study area. It is predominantly low-rise residential development, interspersed with parkland and schools.

Figure 19 - Zoning map of Narre Warren (light pink is low-density residential) (DELWP, 2016)



This does not satisfy best practice, as outlined previously in this paper. A mix of uses is considered to generally provide the best outcomes in urban areas. The reasons for this are many and varied, but include encouraging activity in the streets, bringing people close to employment and providing services within walking/cycling distances of residents' homes (State Government of Victoria, 2014).

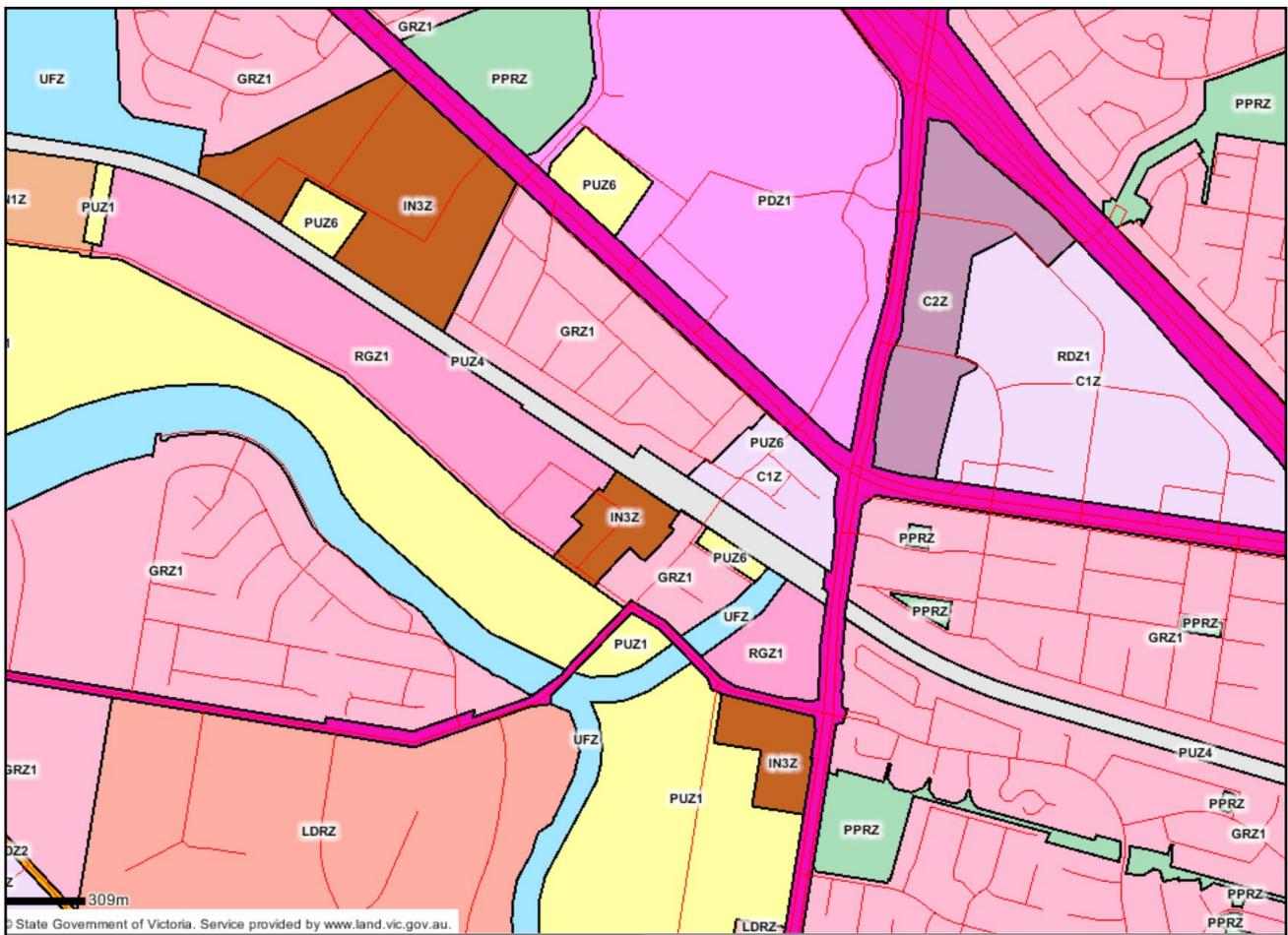
Some examples of this failure to locate land uses in logical proximity to each other include Narre Warren Railway Station and the street networks in residential areas.

NARRE WARREN RAILWAY STATION

The land around railway stations has long been recognised as some of the most valuable and useful land in urban contexts around the world (Roukouni, 2012; Suzuki, et al., 2015; Mulley, et al., 2016). As argued by Dovey & Woodcock (2014), a key part of moving away from car-dependence and towards sustainable transport is to improve density, land use mix and access.

While there is a small parcel of land designated as Residential Growth Zone (RGZ), with high capacity for housing, the other zones adjacent to the station are low-density residential or low-intensity commercial as shown in Figure 20 below.

Figure 20 - zoning map around Narre Warren Railway Station (light pink residential, light grey railway, dark brown industrial, dark pink road)



By including such zoning so close to a railway station, it precludes the benefits of such a location being exploited to their full potential. Accommodating the rapid residential growth occurring on the fringes of Melbourne in medium to high-density mixed use development close to transport hubs would be a far better outcome. This would decrease the reliance on cars and reduce the need or distance to travel overall (Dovey & Woodcock, 2014), creating a more sustainable environment.

In summary, the land use around Narre Warren Railway Station is poor. The mix of uses is small, density is low and access to and from the station impeded by very poor street connectivity. Many opportunities exist to make this precinct around the station a better outcome to integrate land use with transport planning, but to date this has not occurred.

RESIDENTIAL AREAS

As outlined previously in this paper, most land in Narre Warren is residential. This low-rise and low-density development is integrated very poorly with transport planning, as shown by several factors.

The first factor is very poor street neighbourhood permeability. This term refers to the ease with which people can move within and between areas within a particular precinct and is mainly affected by street connectivity (Jiang, et al., 2016). As found by Cervero & Gorham (1995) and others (Zhang, 2004; Echenique, et al., 2012), mobility by public and active transport modes is more affected by the urban environment than simple service provision. That is, even in highly transit-oriented neighbourhoods, public transport commuting is not significantly improved by increased services if the environment around these neighbourhoods was still car-oriented (Cervero & Gorham, 1995).

Due to Narre Warren being largely built by separate private developers at different times, the street connectivity is quite poor. Major transport corridors create significant barriers to non-car-based travel between sections, namely the Princess Highway, Monash Freeway, Pakenham rail corridor and Narre Warren Road. Even local thoroughfares, such as Ernest Wanke Road, are significant barriers due to their huge land footprint and lack of footpaths (OpenStreetMap, 2016). Some examples are shown visually below in Figures 21 and 22.

Figure 21 - No pedestrian crossing at roundabout at Berwick North Shopping Centre (Mallis, 2016)



Figure 22 - Pedestrian-hostile environment at intersection of Princess Highway and Narre Warren Road (Mallis, 2016)



Such restrictions on non-car movements have significant impacts on land use. It is difficult to create a higher-density mixed-use neighbourhood without the necessary ease of mobility between and within neighbourhoods, as such changes rely on active and public transport being more attractive than car usage (Echenique, et al., 2012).

In summary, the land use problems in residential areas of Narre Warren are many and varied, but most ultimately come down to the prioritisation of car usage and a poor mix of densities and uses. The location of medium and high-density residential uses close to logical activity and transport hubs, such as Fountain Gate Shopping Centre and Narre Warren Railway Station, are also not implemented. The primary reason for this situation is the fragmentation of the planning process in greenfield areas such as Narre Warren. With the process of expanding urban areas now largely left up to individual private developers, there is little coordination between the transport activities of governments and the construction activities of developers. This has resulted in a suburb that is poorly planned from a land use perspective in the first place and suffers from a complete absence of integration between transport and land use planning.

EMPLOYMENT AND RETAIL OPPORTUNITIES

One aspect of land use that deserves special attention when analysing its integration with transport is the implementation of commercial, office and retail opportunities from a land use perspective. Contrary to residential zones, at least of these uses are in appropriate locations close to transport hubs.

This point is demonstrated by the fact that the original retail centre, Narre Warren Shopping Centre, is located adjacent to Narre Warren Railway Station and is relatively well-served by metropolitan and regional buses. However, the two modern retail areas, Fountain Gate and Berwick North, are only serviced by buses. Fountain Gate in particular was built only with reference to the Monash Freeway and other major roads with thousands of car parking spaces, but not to any other transport infrastructure. With its status as a regional shopping centre (Scentre Group, 2016), it is particularly instructive that such a large project was not integrated with non-car transport planning at all. Despite it being well-served by multiple bus routes, its location results in a lengthy and time-consuming deviation for all buses in the area. The bus interchange is also located on the opposite side of the shopping centre to the main entrance and does not present an attractive proposition for the bus passenger.

There also appears to have been little or no attempt to densify areas around such employment and retail centres. As outlined earlier in this section, best practice from both the academic literature and practical examples shows that increasing density around employment centres improves the sustainability of mode choice and reduces the need to travel altogether (Nielsen, et al., 2005; Cervero & Gorham, 1995).

In summary, while employment and retail centres in the study area suffer from the same problems as residential areas and Narre Warren Railway Station, there is at least some precedent in the suburb for locating these hubs close to transport nodes. Integrating land use and transport relies just as much on employment and commercial areas being coordinated just as much as residential uses.

■ Proposed Changes

As flagged earlier in this paper, a number of key changes need to occur before Narre Warren can be considered as a place that has integrated land use and transport in an appropriate manner. Using Dovey & Woodcock's (2014) stipulations of density, mix and access, the following key changes are proposed in Table 6 below.

Table 6 - Proposed changes to implement integrated land use in Narre Warren

Change	Description	Timeframe
Intensification	Increase the density of residential and commercial uses near key nodes within the precinct	Medium-term
Improve land use mix	Increase the amount of mixed-use zoning in and around key nodes within the precinct	Medium-term
Encourage active transport	Implement infrastructure improvements to prioritise pedestrian and bicycle travel to increase catchment areas of transport nodes	Short-term

monitoring and evaluation

As outlined by many in the academic literature, it is vital to ensure that projects are monitored and evaluated over the course of their implementation (Clemons & McBeth, 2001; Tomlinson, 2012; Stewart & Lithgow, 2015). This not only ensures that this project achieves its goals, but also provides guidance for any similar undertakings in the future.

With this in mind, a series of monitoring evaluation tools will be used to conduct this exercise once the new network is implemented. Table 7 shows these measures.

Table 7 - Project evaluation framework

Time of evaluation	Type of evaluation
Stage 1 – Before implementation	Stakeholder consultation Costings
Stage 2 – 3 months after implementation	Stakeholder consultation Data collection and analysis
Stage 3 – 12 months after implementation	Stakeholder consultation Comprehensive study on implementation Make any necessary changes based on data collected
Stage 4 – Five years after implementation	Development of network proposal to meet future needs Study on further development

The variety of timeframes ensures that evaluation can occur at every necessary part of the project's timeline. The multiple points of reporting allow data to be collected to determine how well or badly the new network is operating, particularly from the point of view of passengers. Changes can then be made based on this data if necessary.

conclusion

This paper has put forward a strong case for an overhaul of the metropolitan bus system in Narre Warren, as per the project brief. By utilising the relatively new network design framework of Triangle Town, a bus network has been devised with new lines and timetables. While its primary function is to serve as a feeder service to Narre Warren Railway Station, it is also designed to provide a local and sub-regional network in its own right. This includes connections to the nearby activity centres of Berwick and Cranbourne. The most significant single challenge identified within the study area is the lack of integrated land use and transport planning. Almost the entire suburb is designed to prioritise private motor vehicles over sustainable modes of transport. A poor mix of uses, low-density and impeded access are all factors that contribute to this outcome. The changes proposed, while wide-ranging, are not impossible to implement. Future areas for research include examining how to implement good integrated land use and transport planning in Melbourne's new and existing greenfield development suburbs. This will undoubtedly be a challenge that requires multiple fields of research in governance, public policy and urban planning to work together in search of the answers to this question.

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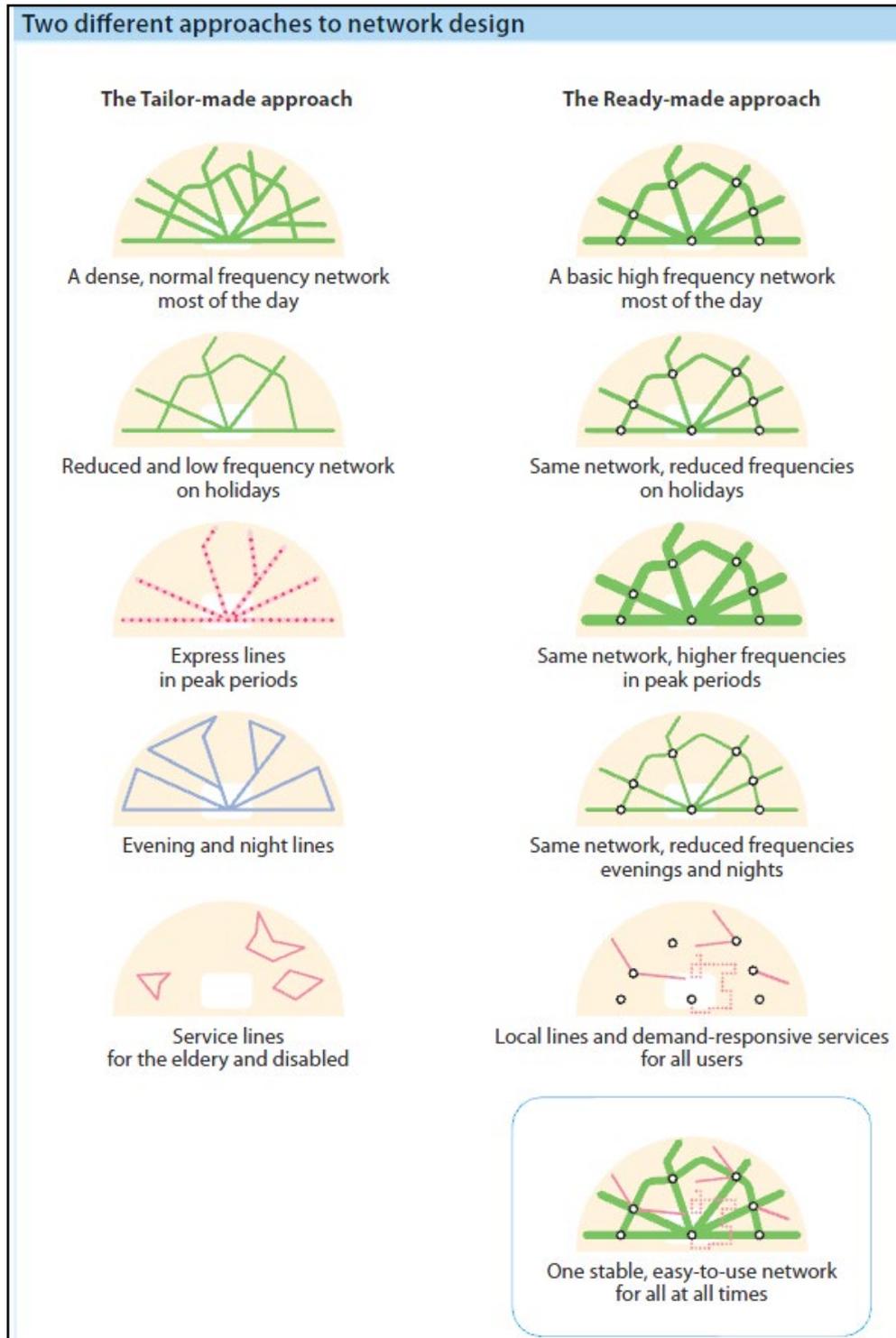
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appendices

■ Appendix A - Network design approaches

Figure 23- Different approaches to network design (Nielsen, et al., 2005)



■ Appendix B - Stage 1 of Network Design Process (Identifying Nodes)

Figure 24 - Commercial nodes (red) (OpenStreetMap, 2016)



Figure 25 - Transport nodes (blue) (OpenStreetMap, 2016)



Figure 26 - Education nodes (blue) (OpenStreetMap, 2016)



Figure 27 - All nodes (OpenStreetMap, 2016)

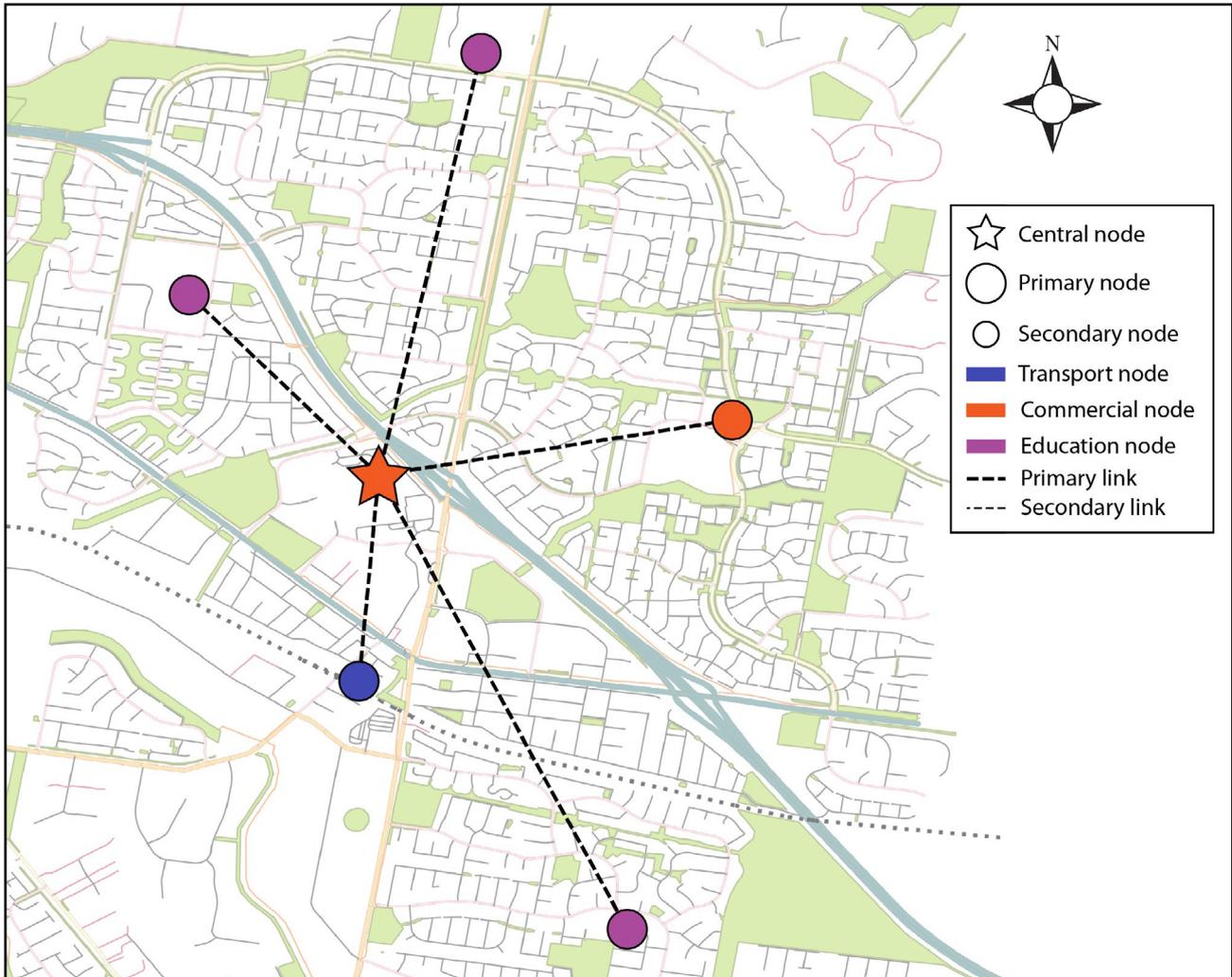


Figure 28 - All classified primary nodes (OpenStreetMap, 2016)



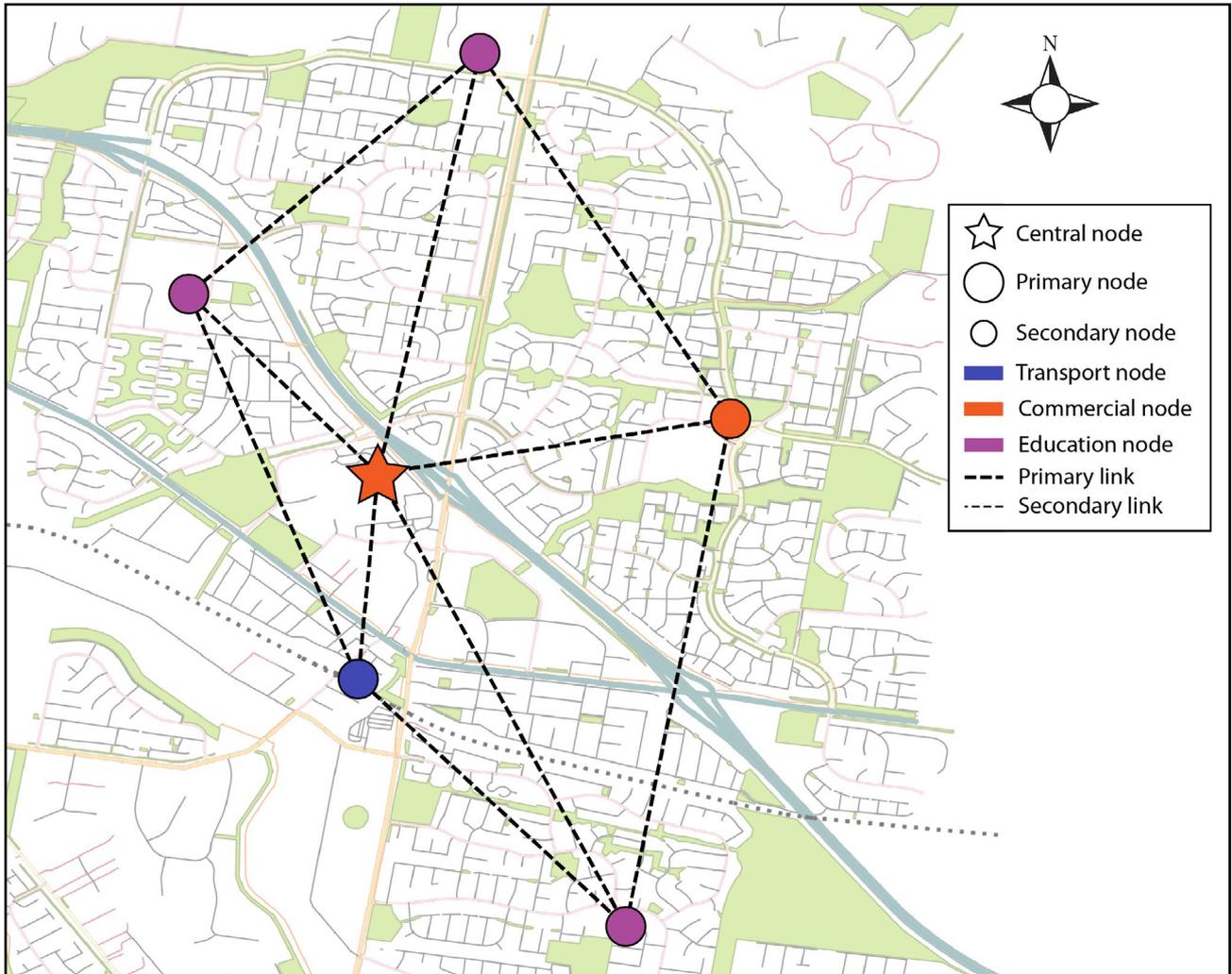
■ Appendix C - Stage 2 of Network Design Process (Connect Key Nodes With Diametric Lines Through Central Node)

Figure 29 - Primary nodes with diametric connections through central node (OpenStreetMap, 2016)



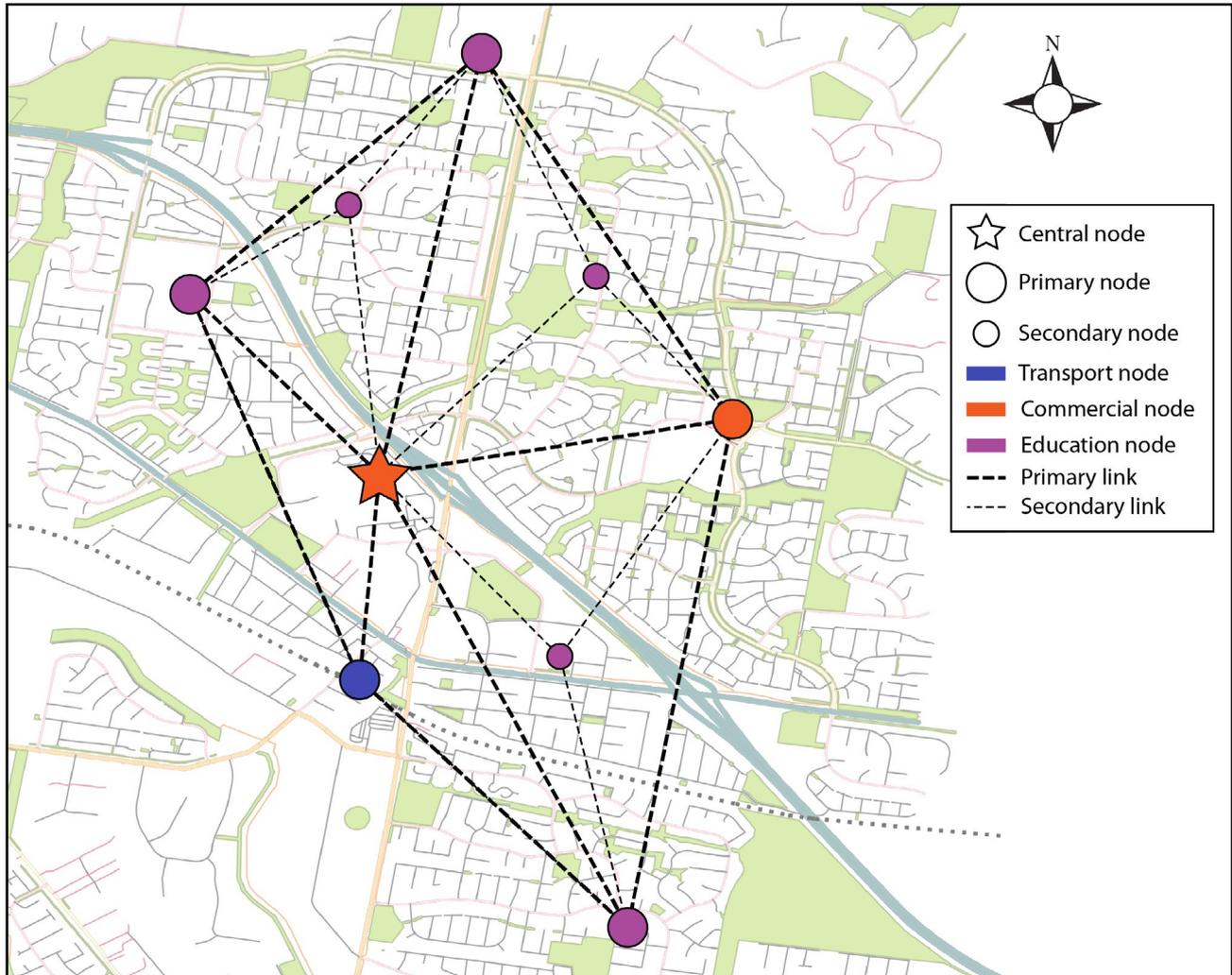
■ Appendix D - Stage 3 of Network Design Process (Connect Key Nodes With Tangential Connections)

Figure 30 - Primary nodes with tangential connections (OpenStreetMap, 2016)



■ Appendix E - Stage 4 of Network Design Process (Connect Additional Nodes to the Network)

Figure 31 - Primary and secondary nodes with connections (OpenStreetMap, 2016)



■ Appendix F - Stage 5 of Network Design Process (Design Lines to Service Triangular Backbone)

Figure 32 - Removal of superfluous connections (OpenStreetMap, 2016)

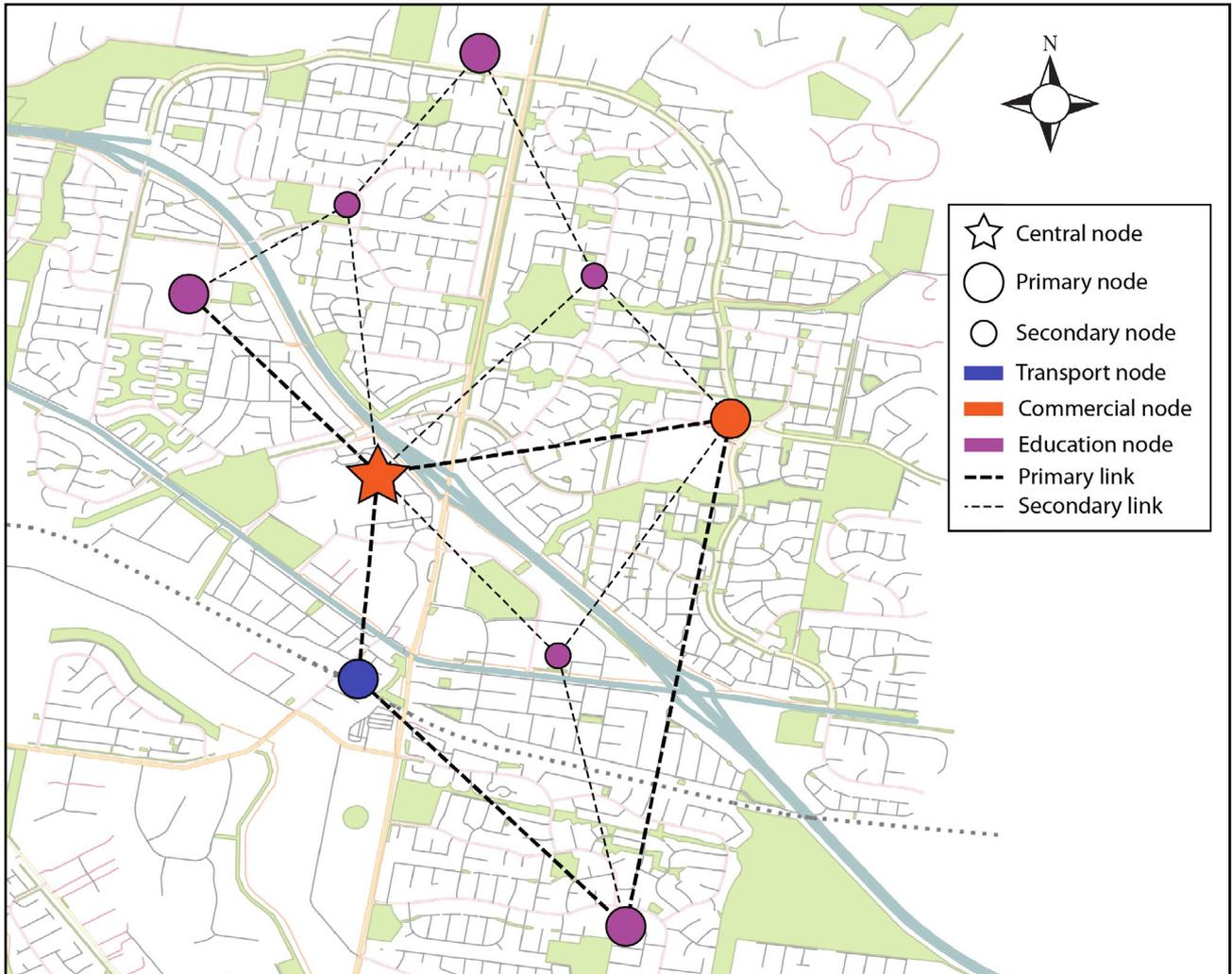
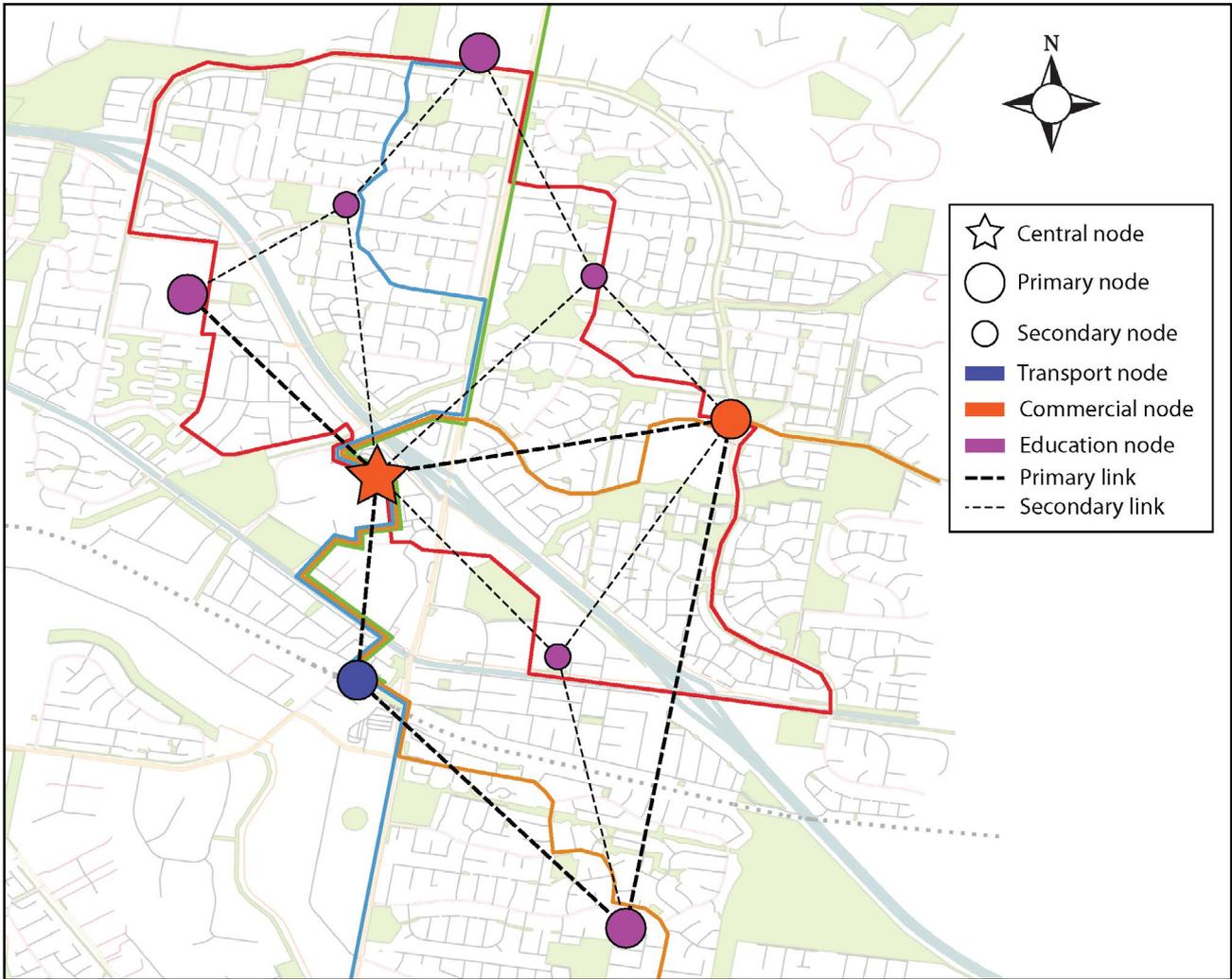
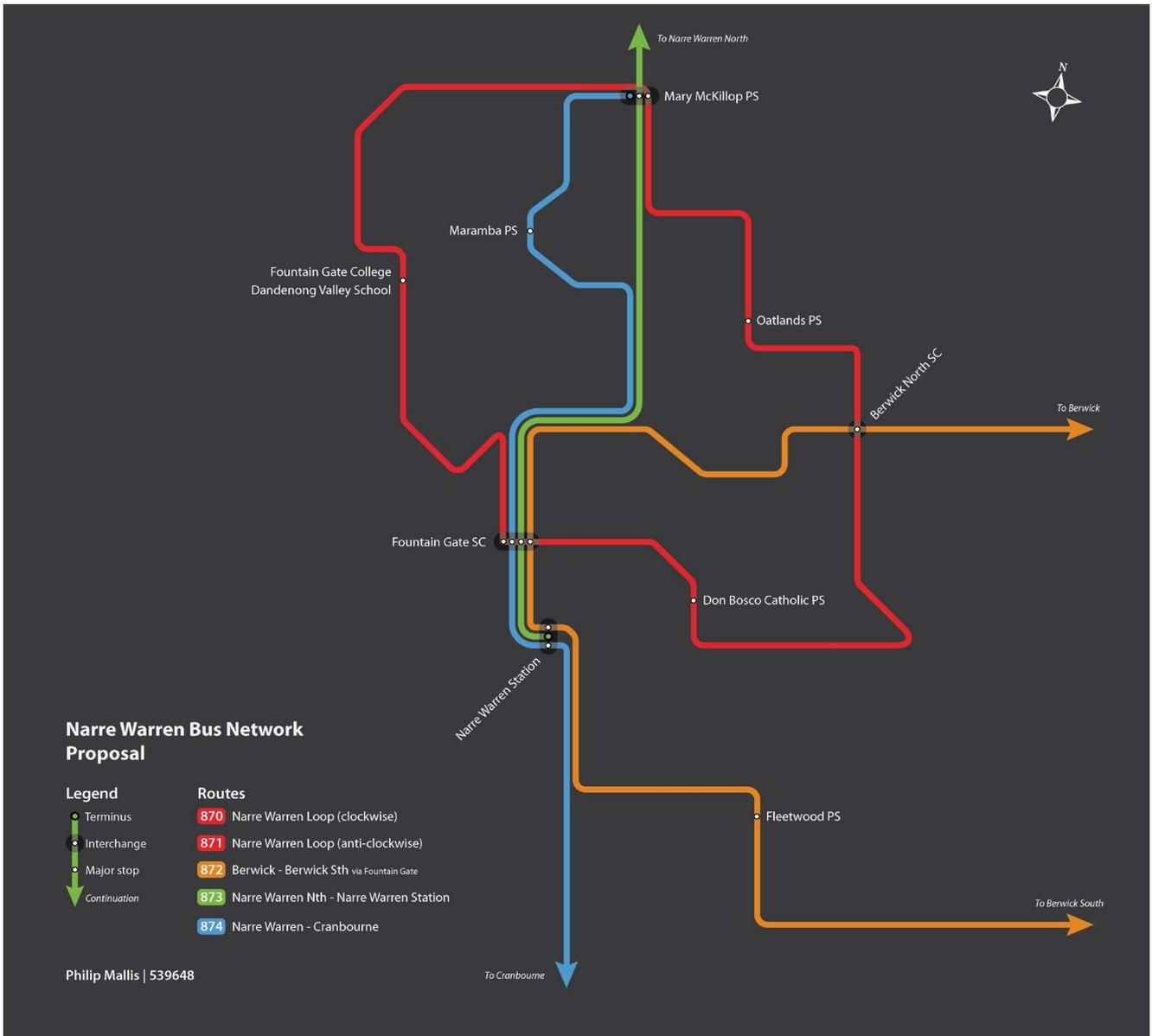


Figure 33 - Line design (OpenStreetMap, 2016)



Appendix G - Dark version of schematic map

Figure 34 - Schematic map of new network (dark version)



Appendix H - Existing train timetable

Figure 35 - Existing Narre Warren Station train timetable (Citybound) (Public Transport Victoria, 2016)

Note: A higher quality version is available on the project website (working link): <http://jellybean.pw/narrewarrenbusproject>

METRO		PT >	
Narre Warren			
To	City (Flinders Street)		
Monday - Friday			
AM			
3			
4	30BK 51BK		
5	11BK 31BK 51BK		
6	11BK 20BK 27BK 35BK 49BK 57BK		
7	04BK 11BK 18BK 32BK 39BK 48BK		
8	02BK 15BK 35BK 55BK		
9	15BK 35BK 55BK		
10	15BK 35BK 55BK		
11	15BK 35BK 55BK		
PM			
12	15 35 55		
1	15 35 55		
2	15 35 55		
3	15B 35 55B		
4	15 35 55B		
5	10 30 44		
6	08 19B 37B		
7	00 10 30B 44B		
8	04B 24B 45B		
9	05B 25B 45B		
10	05B 25B 44B		
11	04B 36BH 36AJ		
AM			
12	35BH		
1	27BH		
2	24BH		
Saturday			
AM			
3	24B		
4	34BK		
5	34BK		
6	22BK		
7	02BK 42BK		
8	22BK		
9	02BK 41BK		
10	11BK 31BK 51BK		
11	11BK 31BK 51BK		
PM			
12	11BK 31BK 51BK		
1	11BK 31BK 51BK		
2	11BK 31BK 51BK		
3	11BK 31BK 51BK		
4	11BK 31BK 51BK		
5	11BK 31BK 51BK		
6	07A 22BK 40A		
7	02BK 20A 42BK		
8	00A 39BK		
9	03BK 33BK		
10	03BK 33BK		
11	03BK 33B		
AM			
12	03B 35B		
1	27B		
2	24B		
Sunday			
AM			
3	24B		
4	24B		
5	24B		
6	24B		
7	02BK		
8	02BK		
9	02BK 41BK		
10	11BK 31BK 51BK		
11	11BK 31BK 51BK		
PM			
12	11BK 31BK 51BK		
1	11BK 31BK 51BK		
2	11BK 31BK 51BK		
3	11BK 31BK 51BK		
4	11BK 31BK 51BK		
5	11BK 31BK 51BK		
6	07A 22BK 40A		
7	02BK 20A 42BK		
8	00A 39BK		
9	03BK 33BK		
10	03BK 33BK		
11	03BK		
AM			
12			
1			
2			
Service Information			
 All services are operated by wheelchair accessible vehicles			
A = Terminates at Dandenong Railway Station (Dandenong) B = Terminates at Flinders Street Railway Station (Melbourne City) H = Operates on Friday only J = Operates from Monday - Thursday K = Operates via City Loop All times are subject to alteration without notice.			
Customer Information			
For more information or to give feedback visit ptv.vic.gov.au or call 1800 800 007			
Effective as of 05 September 2016			
StopID: 19884_DIVA.1139	Stop number: 19884		14.10.2016 15:06:50