# An alternative design principle to transform conventional bus services into a bus transit network

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## Abstract

Urban sprawl is experienced in most Australian cities, including Adelaide, where the majority of the outer suburban areas have limited accessibility to rail-based transport services. These areas are served by conventional bus services and have failed to attract more people to public transportation. As a form of integrated transport and land use planning, bus-based transit-oriented developments (TODs) is considered to be a solution, where the development of a transit corridor and transit services is the first challenge to be addressed.

This paper provides an investigation of an existing conventional bus service with an aim to formulate relevant design policies for a conventional bus service to be transformed into a bus transit service.  It also makes reference to a range of literature in investigating the suitability of a study corridor, i.e. Main North Road, within metropolitan Adelaide, Australia for a transit corridor. A number of computer applications, including ArcGIS, MS Excel, etc., were used to analyse relevant geographic, public bus services related and other literature sourced data.

The findings of this study provide outlines of a design principle for a bus transit corridor transformed from conventional bus services. Although the study examined Main North Road as the study route, the methods used in this paper can be compared and applied to other routes and services of similar characteristics within Australia and internationally.

**Keywords:** Bus-based Transit Oriented Developments (BTODs), Bus Rapid Transit (BRT), Transit corridors, Bus Transit service.

## 1. Introduction

The majority of the outer suburban areas of metropolitan Adelaide are located at least 1km away from the existing rail network corridors. These areas are served by conventional bus services, which constitutes approximately 80% of public transport journeys in Adelaide (The Government of South Australia, 2014). However, the bus services were not found to have expanded with the pace of the population growth and were considered to have deteriorated in quality (Currie, 2014) to attract people to shift away from their usual usage of private cars to public transportation services. The concept of bus-based transit-oriented developments (BTODs) along developed bus transit corridors is considered to be a more viable option for the outer-suburban areas, where accessibility to the existing rail networks are limited, and the conventional public bus services are unattractive (Cervero, 2000). Ho and Mulley (2014) also suggested that traditional bus rapid transit (BRT) style bus services are essential for the fringe areas of metropolitan cities, where communities become dependent on private vehicles because of a lack of general accessibility to direct public transport routes (to the inner cities).

There are some identified disadvantages of the bus based TODs such as i.e. low density, low speed and poor service frequency, lack of magnitude, unknown market implications, etc. (Currie, 2005). Cervero and Dai (2014) have suggested solutions to those concerns and have suggested that the transformation of BRTs into corridors supporting BTODs could be implemented effectively in the context of low-density suburban areas of Australia. The success of a transit service is largely dependent upon the qualities of a service such as pedestrian accessibility and the frequency of services during the weekdays and on weekends, etc. (Taylor et al., 2011). The increased frequency of services is one of the attributes that BRT offers (Ho and Mulley, 2014), which can be linked to an increased number of patronage as the travellers were found to be prepared to walk additional distances to catch an improved frequency bus service (Rose et al., 2013).

The OBahn service of Adelaide, which is the only recognised BRT in Adelaide, was identified to have the potential to facilitate the transformation of the corridor adjacent areas into TODs (Allan et al., 2015), similar to the suggestions made by Cervero and Dai (2014). The OBahn has a unique infrastructure, which is seen by many experts to have enhanced its ability to attract more trips (Bray and Scrafton, 2000, Currie, 2006). However, for a city like Adelaide, where outer suburban areas experience mostly lower density of population and have limited accessibility to rail transport services, the conventional bus route network needs to be closely focused at in providing an improved and attractive services to these communities. Bus-based transit-oriented developments (BTODs) can, therefore, be a potential alternative to the conventional rail-based transit-oriented developments (RTODs) in this city, particularly to service the outer metropolitan suburban areas. Whilst replication of the O'Bahn as a transit corridor in these areas would not be a very realistic consideration (given O'Bahn has a unique setting), the challenge of transforming a conventional shared bus route into a transit service would need to be acknowledged. The availability of a bus transit service, on a transit corridor, has to be considered first before formulating policies for the development of BTODs alongside. The relevant planning policies for Adelaide was supportive of the concept as a number of priority actions were found to be proposed regarding bus based services along Adelaide major arterial routes aligned with the basic principles of transit-oriented development (The Government of South Australia, 2015).

This paper aims to investigate a major arterial bus route (Main North Road) of northern Metropolitan Adelaide, which has already been identified as a route (hence, qualified as a study route) with the potential to be transformed into a BRT corridor to support transit-oriented developments (TODs) in adjoining areas.  This study has examined the study corridor in light of the design principles of BRT services and has developed a policy outline for an achievable bus transit service along the corridor.

The approach and the methodology of the study, as are presented in Section 2 of the paper, can be applied to any conventional bus routes of similar characteristics to achieve a similar result. Section 3 discusses the potential of Main North Road as a BRT corridor in light of the relevant literature. The analysis of the existing infrastructure along Main North Road and the levels of existing bus services are discussed in Section 4, which provided the underpinning background of the formulation of alternative service design principles are discussed in Section 5 of the paper.

# 2. Methodology

## 2.1 Selection of the Study Area and Study Route

As part of a broader research, five of the key bus routes (both existing and new routes including new roadways) within the north-eastern parts of metropolitan Adelaide were considered as initial candidate corridors in determining the study corridor for the research. A two-step process was followed, where an independent suitability analysis of the five corridors was undertaken based on nine selected parameters, and then a multi-criteria decision analysis was undertaken to obtain the final results. The results were quantitative and were represented as ‘suitability scores’. The collective results revealed that ‘Main North Road’ would be the most suitable corridor for transformation into a transit corridor for a BTOD model and hence, Main North Road was selected as the case study corridor for this research.

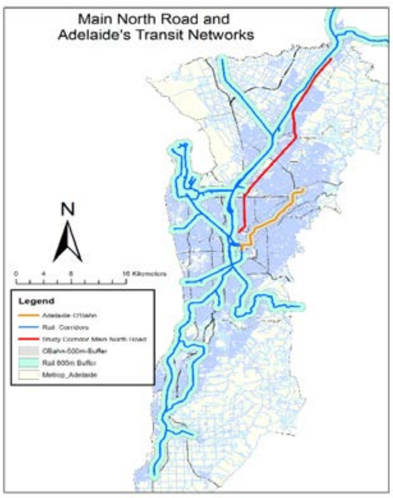

Figure 1: The Study Corridor in Context of the Northern Region of Adelaide

Figure 1 represents the location and orientation of Main North Road, the study corridor, in the context of the existing transit networks and their catchments within metropolitan Adelaide.

## 2.2 Review of Literature

A review of a range of literature was undertaken on the concept of Bus Rapid Transit (BRT). Some works were found to have extensively looked into the design features of the services (i.e. infrastructure and service patterns), while many were found focused on the impacts of BRT services in attracting more public patronage. Case studies from across the world were found used in those works. A broader understanding of the BRT infrastructure and the design requirements was gained as a result of this review (discussed in section 3 of this paper) and was considered in the context of the study corridor.

The design principles developed from the literature review were further refined and was compared to the existing infrastructure of the study route in identifying the actions required to transform the bus route into a transit corridor.

## 2.3 Corridor data analysis

The study corridor, Main North Road, is one of the busiest bus corridors within metropolitan Adelaide and is presently used by a number of bus routes to different destinations. The bus routes and timetable data were obtained from the Adelaide Metro website, and were analysed to estimate the basic level of services that the study route offers.  The Main Road data of metropolitan Adelaide region was obtained from the South Australian government data directory (The Government of South Australia, 2016), which provided the total approximate length of the study corridor along with other relevant information. Virtual observation via 'Google Streetview' tool was used to obtain infrastructure and service related information along the corridor (i.e. existing laneways, road width, existing carriageway width, existing bus routes, etc.).

ArcGIS was used to analyse the existing transport corridors of metropolitan Adelaide and analysing the existing arterial and local bus routes along the study corridor.  A number of maps were also produced using ArcGIS to demonstrate different elements of the analysis.

# 3. A bus transit service: Opportunities and challenges for Main North Road corridor

The potential of an uninterrupted bus running-ways, with the support of well-designed ITS services, was considered to provide an opportunity for reconsideration of the existing bus service patterns.  A well-designed bus service network plays an important part in achieving a successful corridor design.  The expected improvements in the frequency and travel time of the existing bus services along the study corridor could also allow consideration of a framework for a new high-frequency bus transit service similar to the characteristics of a rail-based transit corridor, where the transit bus would run along the corridor and would be integrated with other arterial bus services and many new and existing local/ feeder services.

Relevant literature (Currie and Lai, 2008, Jiang et al., 2012, Levinson et al., 2003, Kepaptsoglou and Karlaftis, 2009) suggest that a continuing and well-coordinated busway can be considered as the first design component to be achieved in a successful BRT system. It cannot perform alone in securing higher frequency of services for the users that offer lower travel times. A coordinated support is essential in the design and operation from other BRT components such as; safe and accessible stations and vehicles, Intelligent Transport System (ITS), co-ordinated service patterns and easy ticketing systems (Levinson et al., 2003, Wright and Hook, 2007).

The design of the "stations" for Main North Road was not considered to be needed as large or as aesthetically attractive as was suggested by Wright and Hook (2007). The existing bus stops were considered to function quite effectively in providing the required accessibility to transit services along the corridor. The importance of safe and secure environment at and around the stations for accessing public buses was not underestimated and was considered that must be evaluated and improved at all times regardless of the type of services available. The 'vehicle', as a design component for Main North Road, represented a similar argument as the 'stations', where it was expected that the existing bus fleet could just provide the same services as would the existing bus stops would provide. A new fleet of articulated buses was not considered to attract significant regular patronage unless the level of service frequencies and the travel times were visibly improved. With the availability of uninterrupted (and prioritised) busways, an improved level of services was expected to be provided with support from the same bus fleet. The application of smart "fare collection" methods and technology was identified as an important component in improving the efficiency of a BRT service. However, this was considered to be very relevant for an environment, where passengers would be difficult to manage in a crowded station environment. Considering the socio-economic and demographic characteristics of outer metropolitan Adelaide suburbs, this component was not expected to play a very influential role in the success of a BRT.

The success of the BRT running-way would be largely dependent upon the success in appropriate designing of the Intelligent Transportation System (ITS). This may include the installation of the bus priority signalling system at the intersections and may also include the bus detection systems along the running-ways. The modern Automated Vehicle Location (AVL) on vehicles linked with the Geographic Positioning Satellite (GPS) technology can provide an effective design solution for the BRT corridor (Wright and Hook, 2007), where approaching buses can be identified beforehand and the signals could be adjusted accordingly either to provide an extended period of ‘green time’ or to process a ‘bus only’ priority immediately (Levinson et al., 2003). Main North Road was found to have bus priority lanes at a number of intersections, but the signal arrangement was not observed to be sufficient to allow a prioritised and uninterrupted bus movements along the corridor.

Table 1 represents a summary of the BRT design features and standards as discussed by Levinson et al. (2003), Levinson et al. (2002), Adam et al. (2005), Hensher and Golob (2008), Currie and Delbosc (2011), and Wright and Hook (2007). Based on the discussion above, the significance of the identified design components was compared in the context of the study corridor (Main North Road) and the components were ranked as demonstrated in Table 1 below. The table also shows a brief assessment of the corridor against the design standards.

**Table 1: BRT design features and Main North Road corridor**

| BRT Components | Rank | Design Features and standards | Main North Road Characteristics |
|---|---|---|---|
| Running-ways | 1 | • Exclusive right of ways<br>• Bus lanes in mixed traffic<br>• Shared lane on streets | • A mix of all three options would need to be used. |
| Intelligent Transport System (ITS) | 2 | • Automatic vehicle location (AVL) system;<br>• Passenger information on board and at station;<br>• Special priorities for bus lanes or timing priorities for buses at intersections. | • Bus priority lane was found at five intersections<br>• AVL is not known to be widely used in buses |
| Service Patterns | 3 | • Can operate beyond the running-ways;<br>• Demand-driven ‘express’ or ‘all stop’ service;<br>• Local/ feeder bus services may integrate. | • Existing bus services have the potential to transform into one Bus Transit service |
| Stations | 4 | • Safety and accessibility are very important<br>• Can be designed as simple sheds to architecturally designed building<br>• Overhead pedestrian crossing is often required | • Mixed types of stops were found from the safety and security, cleanliness and design point of view. |
| Vehicles | 5 | • Generally articulated types of buses.<br>• The floor level depends on the designed services.<br>• Internal spaces and appearance are important. | • Most buses are equipped with disability access<br>• Most have wide internal spaces and good appearances |
| Fare collection | 6 | • Fares could be collected at stations, before boarding the vehicles<br>• It is dependent upon the types of stations, vehicles and the demand. | • Fares are collected onboard near the entrance at the front<br>• Includes smart ticketing system, accepted to all forms of public transport services. |

The success of a transit service would not be achieved unless a complete coordination is established among all BRT design components. The suggested ranking in the above table just indicated the authors’ understanding of the design priorities necessary to achieve uninterrupted busways, which was considered to be the first BRT design challenge to be met because of the presence of many location-specific practical constraints of the study corridor. Proper utilisation of the existing available infrastructure was also given significant weight in the study so that both the construction and operational phases of such a project could become cost-effective and could be visibly viable.

# 4. The Study Corridor Analysis and Results

The Melbourne SmartBus experience was considered to be more aligned with the aim of this study in identifying a cost-effective and faster infrastructure improvement mechanism to convert a conventional arterial bus route into a bus transit corridor. Similar to the SmartBus services, the study corridor also appeared to have the potential to serve the outer metropolitan areas by using a mix of bus right of ways within the existing built-up areas (Currie and Delbosc, 2011).

In light of the discussion above, this paper first attempts to assess the capacity of the study corridor to accommodate the bus running-ways as the first priority for a BRT transit. Secondly, this paper analysed the existing bus routes/ services along the corridor and within the northern catchment areas with an interest to formulate a design framework for an alternative network of bus services. The design components as considered within the scope of this paper are as follows:

## 4.1 The existing bus services along Main North Road

Five conventional arterial bus routes/ services were identified running along Main North Road servicing the suburban areas of Prospect, Nailsworth, Enfield, Blair Athol etc. within the first 8kms of the Adelaide Central Business District (CBD) and the farther suburbs of Mawson Lakes, Pooraka, Para Hills, Salisbury, Elizabeth, Smithfield to the north. Figure 2 demonstrates these services and their existing catchments along Main North Road. These routes appeared to have been designed mainly to connect the CBD to the northern suburbs, via the main arterial study corridor and through the local neighbourhood roads. One of the services (Route 225 to Salisbury Interchange) was found only to provide peak services, while another (Route 222) was found to have options for transfer to and from another bus service (i.e. Route 228). Services were also found to operate under different numbers denoted as X, F, N, R etc., which represents the patterns of services during the day (The Government of South Australia, 2017).

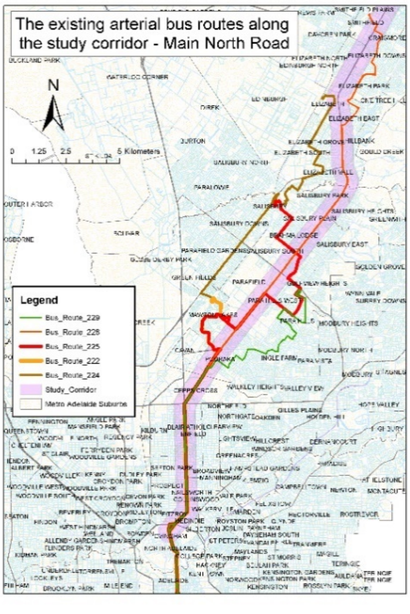


Figure 2: The Existing Arterial Bus Routes along the Study Corridor

Table 2 provides the details of the service patterns. The table shows that among all five services, Route 222 was designed to make the highest number trips during the weekdays at the best average peak frequency of 8.78 minutes and at the second best average peak travel speed of 19km/hour.  Route 225 only provided complete trips during the peak hours (total of 8 and 9 to and from the CBD) at the worst average frequency of 22.63 minutes while was estimated to be the fastest in travel speed (18.65 km/hour).

Table 2: The existing northern bus routes along Main North Road (MNR) from Adelaide CBD

| No | Route No | Services (Origin-Destination) | Route Length (km) | Total Services (weekdays) | | Avg. Peak Frequency (in minutes) | Avg. Peak travel time (in minutes) | Avg. Peak Speed (Km/Hr) | Usage of Main North Road (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | To CBD | From CBD | | | | |
| 1 | 222 | CBD to Mawson Interchange | 16.73 | 58 | 59 | 8.78 | 52.8 | 19.0 | 53.0 |
| 2 | 224 | CBD to Elizabeth Interchange | 33.30 | 34 | 37 | 18.55 | 93.50 | 21.37 | 26.6 |
| 3 | 225 | CBD to Salisbury Interchange | 24.63 | 8 | 9 | 22.63 | 79.2 | 18.65 | 44.4 |
| 4 | 228 | CBD to Smithfield Interchange | 28.59 | 39 | 38 | 12.51 | 75.25 | 22.8 | 74.8 |
| 5 | 229 | CBD to Para Hills | 22.64 | 27 | 31 | 23 | 61 | 22.27 | 34.8 |

Figure 2 also shows the segments of the study corridor that these services use at the different levels of frequencies during the day. As it appears, the segment between O'Connell Street, North Adelaide and Montague Road, Ingle Farm benefits the most in getting access to all these services. These areas evidently experience the highest level of frequencies to and from the CBD, which was also found to be recognised by the Government of South Australia's promotional idea of "GO Zone", which offered convenient access to public transport to the users within during the days in weekdays with a waiting time of up to 15 minutes (The Government of South Australia, 2017).

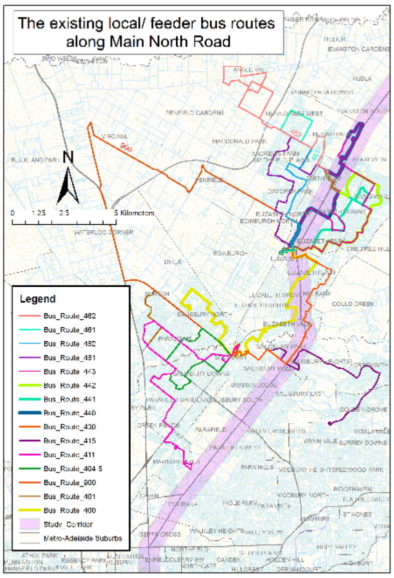


Figure 3: The Existing Local Bus Routes along the Study Corridor

A number of local and feeder routes were also found serving the northern part of metropolitan Adelaide. These bus routes appeared to have been playing a significant role in improving accessibility to the local communities. This study identified some of these routes, which either have direct connections to or have potential to be connected to the corridor. Figure 3 demonstrates such fifteen (15) local bus routes which appeared to have been designed to provide a network among the communities and the key activity centres such as, shopping centres, the transport interchanges etc.

Along with the abovementioned five major routes, a number other arterial routes were identified to have been using the northern segment of Main North Road. These services included Route 238 (connecting the CBD and Mawson Lakes via Churchill Road) and Routes 500, 501, 502 connecting Elizabeth, Mawson Lakes and Salisbury interchanges respectively via the Adelaide O'Bahn.

## 4.2 The capacity of Main North Road to become a bus transit corridor

As part of this study, the capacity of the Main North Road was carefully assessed to find out whether it could provide uninterrupted (or interruptions at minimum level) services along the corridor. In principle, the capacity of the corridor was assessed based on a key consideration of its ability to allow utilisation of the majority of its existing infrastructure, thus requiring a minimum level of road improvements or modification works resulting in a minimum disruption on the existing traffic condition and disturbances for the adjoining communities.

As part of the authors' overall research, a method was adopted to consider the existing sealed segments of the carriageway (width) as an attribute, which can otherwise be explained as a segment that could accommodate a bus lane causing minimum impact on the existing traffic movements. The analysis took the sealed segment of the carriageway width as an attribute instead of taking the overall road right of way (i.e. from one edge of the observed private property boundary to the other) because of the same consideration that any new works would cause disruptions.

The study corridor (Main North Road) was observed to have varied carriageway widths and traffic lane arrangements at different locations. The lane widths were found wider than the standard in many areas with at least the road width available for two (2) traffic lanes in one direction. For understanding the suitability of the study corridor, the capacity of Main North Road was compared with four other key arterial roads that share similar characteristics. These were Churchill Road, Prospect Road, Hampstead Road and North East Road. Churchill Road was slightly modified from the exact existing bus routes to allow for a potentially long, straight and continuous bus-way. A suitability classification was developed on the basis of the existing sealed sections of the roadways as the respective route's capacity attribute. Five suitability criteria were developed ranging from the "least suitable" (given weight = 1) to the "most suitable" (given weight = 5), which represented the attributes of "maximum two lanes" gradually upwards to attribute of "six lanes and wider" respectively. A "suitability score" was calculated for each of the initial corridors based on the total length availability of the sealed sections along the corridors. The final scores of the initial corridors were compared, and the results showed that Main North Road would be the most suitable corridor with a total suitability score of 162.5 and the average score of 4.85.

This study further looked into the details of the available infrastructure of the first 11km (approximately) of Main North Road, where the corridor appeared to provide more constraints than the northern segments. The results found that the majority of the corridor length would be suitable to be transformed allowing a bus lane along each side. Table 3 represents a summary of the observed dimensions (sourced from Google Maps) of carriageway widths of Main North Road at different segments.

Table 3: The existing capacity of Main North Road (from North Adelaide to Maxwell Road Intersection)

| No | Carriageway Width (in metres) | Corridor Length (in metres) | Number of marked lanes | % of Corridor Length | Notes (* Corridor Length = 21km) |
|---|---|---|---|---|---|
| 1 | Up to 14.5m | 438 | 4 | 2.09 | |
| 2 | 15.6 | 150 | 4 | 0.71 | Between Charlbury Rd and Sefton Plaza south access |
| 3 | 17 - 20 | 1685 | 4 | 8.02 | |
| 4 | 18 - 19 | 1245 | 5-6 | 5.93 | |
| 5 | 18 – 21 | 645 | 4 | 3.07 | One parking lane on both sides |
| 6 | 18 – 22 | 410 | 6 | 1.95 | |
| 7 | 18 - 26 | 2632 | 4 | 12.53 | One bike lane on both sides |
| 8 | 20 -21.5 | 1100 | 4 | 5.24 | One parking lane on both sides |
| 9 | 20 – 21.5 | 656 | 5-6 | 3.12 | One parking lane on one side |
| 10 | 21 - 25 | 95 | 7 | 0.45 | |
| 11 | 21 - 32 | 1822 | 6 | 8.68 | A 527m long bus-lane identified along the western edge of the corridor |
| 12 | 31 – 36 | 970 | 9-10 | 4.62 | Major road intersection areas |

Main North Road was identified to have a minimum capacity of 4 lanes (two-ways) within the segment between O'Connell Street and Fitzroy Terrace, with a carriageway width of 14.5m approximately. The segment between Fitzroy Terrace and Grand Junction Road has a mixed capacity of a minimum of 4 lanes to 9 lanes carriageway with varied traffic lane arrangements. The population and employment density were identified to be the highest in this segment of the corridor. A diverse nature of local and thorough traffic and necessary traffic arrangements were identified along this segment. This segment of the road was observed to have a minimum width of 17m with an exceptionally low width of 15.6m over an only 150m length along the corridor. Approximately 2.4 kilometres of the carriageway was found in this segment of the corridor having allocated marked on-street parking provisions either on one side or both sides of the corridor, which constitutes approximately 11.43% of the corridor.

In contrast, the study corridor was found to have different characteristics from Grand Junction Road towards the north. An extensively wide road right of way was identified along this segment (compared to the first 8km from the CBD). This segment of the corridor was found to contain wide intersection areas with a width of up to 36m (with 9-10 marked lane capacities), while the other sections of the roadways found to have widths of at least 20m with a minimum of four carriageway lanes.

From a consideration of the corridor as a whole, the likely outcome for the busway appeared to be a mixed of all running way options, i.e. on street, shared and dedicated bus lanes, and segregated bus lanes with the exclusive right of way. A width of 17.5m was estimated to be the minimum requirement to cater for four (4) standard traffic lanes and Two (2) bus lanes (six lanes in total). As Table 3 shows, approximately 2.8% of the corridor does not qualify this minimum width as was roughly estimated for this study. Approximately 8% of the corridor length shows a lower capacity with a varied width ranging 17-20m. Although the study corridor started from O'Connell Street, North Adelaide, Fitzroy Terrace intersection appeared to be the starting point for the bus-lanes. With the support of a proper ITS design, buses can, however, receive a priority at the signal while approaching the intersection of Fitzroy Terrace. Within the segment of Fitzroy Terrace and Grand Junction Road, where the corridor is identified to have a fluctuating width in some areas (particularly between Shelbourne Road and Regency Road), Intermittent bus lanes could be considered open for other traffic to share the lane with appropriate care.

# 5. Main North Road and a potential Bus Transit Service

## 5.1 The impact of a transit corridor on transit services

A study undertaken by Hensher and Golob (2008) showed that when a number of independent variables such as fares, the number of stations and their distances, average speed, average service frequencies, vehicle capacity, etc. were considered to identify their influence over the selected dependent variable of BRT patronage, more stations, more frequencies and capacities of services were found to have potentially increase ridership.

Levinson et al. (2003) compared 26 BRT case studies across North and South America, Europe and Australia, and have categorised the services into three general types based on the nature of bus running-ways of those services. The services that run on a combination of running-ways (i.e. including on exclusive right of ways, median reservations, bus lanes and mixed street traffic) they compared those with the services similar to the light rail transits. In relation to the service performances, they identified an increase in the public ridership, for Adelaide, the results showed that there was a 76% gain in the ridership. In regards to the travel speed and travel time, it was estimated that bus lanes on arterial city routes could save a maximum of 1.25 minutes/ km (a minimum of 0.63 minutes/ km) compared to savings of up to 1.88 minutes/km for the buses on the grade-separated exclusive right of ways.

Currie and Delbosc (2011) examined the influence of the ‘right of way’, as a key BRT design feature, on ridership. The study found the SmartBus routes to have the highest service level on both annual vehicle trips and weekday frequency despite not having segregated right of ways. One of the supporting measures was to have a closer stop spacing.

## 5.2 The impact of the study corridor on the existing bus services

The study corridor, Main North Road, is an arterial road/ bus-route, where buses share the existing lanes with mix traffic. Although the study acknowledged a number of challenges, it demonstrated in the earlier sections that the roadway can potentially be transformed into a corridor accommodating bus lanes on both sides. A continuous and uninterrupted bus-way was considered to have an impact on the bus travel times, which, along with many other factors (e.g. service frequencies, costs, comfort, safety etc.) can be considered as a key determining factor for the users to choose buses against private cars. This paper demonstrates an analysis of the design bus travel times of the existing five (5) bus routes with an intention to understand the potential improvements that the discussed corridor may achieve.

Table 4 shows an analysis of the different components of the existing bus services and the results show that the introduction of continuous bus lanes can improve peak travel time by a maximum of 38.54%. In the calculations, the characteristics of a corridor were considered to be provided only by Main North Road at this stage, and hence, all changes to the travel estimations were subject to the length of the corridor that the respective existing bus services were using. It was difficult to estimate the travel time (per kilometre) along Main North Road as it was not a direct form of data available. Google Journey Plan tool was used to obtain bus travel times for five different segments along the corridor and, a final average was taken as the corridor travel time to be used in the overall corridor analysis. Refer to Table 5 for the detailed estimation. The estimated average was 2.71 minutes per km. In estimating the potential improvements in travel times, a minimum of 0.63 minutes/ km and a maximum of 1.25 minutes/ km were subtracted from the corridor travel time as were found by Levinson et al. (2003) as possible time savings outcomes in their research.

Column 12 of Table 4 demonstrates that with the highest rate of savings as suggested by Levinson et al. (2003), a minimum of 14% improvements in travel times would be achieved for the existing Route 224, which constitutes the longest route lengths among the selected five routes. The savings in the peak travel times for the Route 228 – CBD to Smithfield, on the other hand, was found to be a highest 38.54%. The analysis also looked into the minimum rate as was suggested by Levinson et al. (2003), which is provided in Column 13 of the table.

Based on the discussions as above, it was expected that transformation of Main North Road into a transit corridor would improve the level of services of the existing services in its current form.

Table 4: The results of the Travel time analysis of the existing bus routes along Main North Road

| (1) Route No | (2) Services | (3) Route Length (in Km) | (4) Average Peak Travel Time (in Mins) | (5) MNR* Segment (in Km) | (6) Existing Average Bus Travel Time** via MNR (Mins/ Km) | (7) Existing Bus Travel Times on MNR | (8) Existing Bus Travel Times on Other Roads | (9) Max. Improvement on Arterial Road (1.25 Mins/Km) | (10) New Potential Travel Time on MNR | (11) New Total Bus Travel Times | (12) Maximum Achievable Time Savings (in %) | (13) Minimum Achievable Time Savings (with 0.63 Mins/Km) (in %) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 222 | CBD to Mawson Interchange | 16.73 | 52.8 | 9.36 | | 25.37 | 27.43 | | 13.67 | 41.10 | **22.16** | **11.17** |
| 224 | CBD to Elizabeth Interchange | 33.3 | 93.5 | 10.52 | | 28.51 | 64.99 | | 15.36 | 80.35 | **14.06** | **7.09** |
| 225 | CBD to Salisbury Interchange | 24.63 | 79.2 | 12.66 | 2.71 | 34.31 | 44.89 | 1.46 | 18.48 | 63.38 | **19.98** | **10.07** |
| 228 | CBD to Smithfield Interchange | 28.59 | 75.25 | 23.2 | | 62.87 | 12.38 | | 33.87 | 46.25 | **38.54** | **19.42** |
| 229 | CBD to Para Hills | 22.64 | 61 | 8.35 | | 22.63 | 38.37 | | 12.19 | 50.56 | **17.11** | **8.62** |

Source: Metro Adelaide Bus Travel Times, Google Journey Planner Tool.

***** - Main North Road
****** - Average is calculated for five separate segments along MNR as shown in Table 5 below

Table 5: Calculation of an Average Travel Time/km along Main North Road

| No | Bus Stops (along Main North Road) From | To | Routes | Road Distance (in Km) | Travel Time (in minutes) | Travel Time / Km | Average Travel Time /Km |
|---|---|---|---|---|---|---|---|
| 1 | Stop 7 | Stop 32 | 228 | 8.33 | 25 | 3.00 | |
| 2 | Stop 7 | Stop 30 | 229 | 7.61 | 24 | 3.15 | |
| 3 | Stop 7 | Stop 39 | 228 | 12.14 | 29 | 2.39 | **2.71** |
| 4 | Stop 7 | Stop 32 | 224F + Train | 8.33 | 24 | 2.88 | |
| 5 | Stop 7 | Stop 58 | 228 | 20.84 | 44 | 2.11 | |

Source: Metro Adelaide Bus Travel Times, Google Journey Planner Tool.

## 5.3 The potential of a Bus Transit Service (trunk) along the corridor

Table 4 above demonstrates an interesting finding; the level of improvements in travel times is completely dependent on the length of the corridor that the respective bus services use. The best example would be the comparison between the routes 224 and 228. Although the route length of Route 224 was longer than Route 228, the usage of Main North Road by Route 228 was found to be more than double; 10.52km as opposed to 23.2km respectively. The usage of Main North Road was found to make a very clear difference in the improvements of the respective travel times of those routes; 14% and 38.5% for Routes 224 and 228 respectively.

This analysis broadly suggests that the increase in the use of the corridor (Main North Road) would support quicker travel times for the destinations which would continue to be accessed via the corridor. Based on this consideration, this paper makes an alternative design suggestion (to keeping the existing services as is) to introduce a new high-frequency trunk bus transit service along the corridor. The key supporting design principle would be similar to the characteristics of a rail-based transit corridor; i.e. the transit would run along the corridor only and would be connected to a network of local and feeder services at a number of connection points. Figure 4 demonstrates a concept design of a Bus Transit service, where the major bus transit would run along Main North Road corridor and the existing segments of the bus routes, off Main North Road within the suburban areas, would be transformed into interconnected local services.

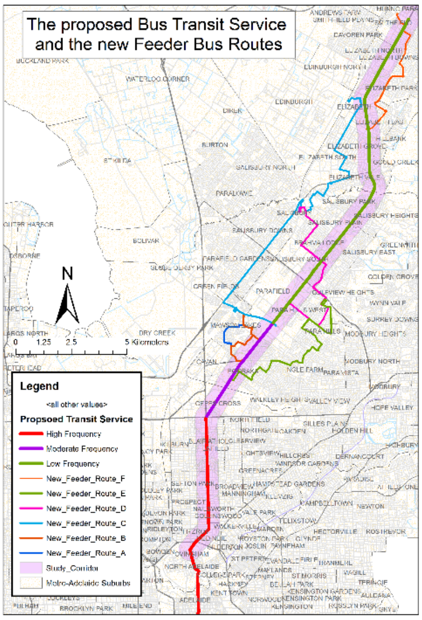


Figure 4: The concept design of the interconnected network of Bus Transit and new Local Bus Services.

The key features of the concept can be summarised as follows:

- The Bus Transit service was proposed to have a simple route name (or just one number), which would clearly interpret the extent and the types of services in the users' minds. It would remove all ambiguities associated with the existing tens of route numbers and their service patterns.

- The central Bus Transit would run in three segments in accordance with the varied needs/ demand of service frequencies. For example, the existing high-frequency service areas, otherwise recognised as the “Go Zone”, would continue to receive similar frequency services. The red segment in the figure shows the high-frequency service areas, which is located between O’Connell Street and Grand Junction Road. The purple and the green segments represent the low frequency needs to further north.
- A corridor only Bus Transit was expected to provide a higher frequency of services and provide lower travel times for the existing users as is generally expected from a rail-based services.
- New local services could initially follow the routes of the existing services with safe accessibility and improved information provisions along the corridor. The timetables of these services would have to be aligned with the central Bus Transit service so that the passenger transfer times could be maintained to the minimum level.
- The fifteen identified existing local services were considered to have immense potential to integrate with the proposed corridor. The extensions of the routes might be needed to connect to the corridor, while a minor timetable adjustment would work for some.
- The passenger transfer / waiting time at the stations could be further improved by synchronising the other arterial bus routes such as, 238, 500, 501 etc., which were found either to use part of the corridor or to connect at intersections. Such potential connection points could at the intersection of Montague Road or Smiths Road.
- From a rough estimation, it was considered that there would not a major change of operation required to shift from the existing services to the proposed Bus Transit service. The proposed services would replace the existing bus routes; hence, cost implication not be unreasonable. Initially, a part of the existing fleet would be engaged as the Bus Transit (with appropriate branding off course), while the remainder of the fleet would perform as the local services. The additional costs of achieving the higher level of frequencies and services would remain the same as this would have needed to achieve an improved level of services from the existing bus services anyway.

# 6. Conclusion

Although some users might very likely to feel reluctant in accepting the introduction of the transfer requirements at the stations/ stops, a good promotion of the improved service (i.e. better frequencies and better travel times) might help to balance this disadvantages. People would need to be informed of this unique infrastructure and the long-term benefits of it. Development of an image and branding of the new services were considered critically important as proper branding has the potential power to change the perception and profile of the bus transit. It can also improve legibility of the service attractiveness for existing and new users. A market research for Route 903, Routes 905, 906, 907 and 908 of Melbourne SmartBus services found that 72% and 62% of the survey respondents became aware of the service from either the bus brand livery or the new service-oriented advertisement campaign (Devney, 2011). Therefore, proper marketing or branding of the proposed BRT corridor and the improved services can be expected to attract a significant number of people to a modal shift to the public transportation. Direct public participation was regarded as an integral part in the formulation of design and policies, and therefore, any potential outcomes from any future studies need to be well promoted to the general public to ensure that they are well informed of the positive impacts of any potential changes (Planning and Transport Research Centre - PATREC, 2005).

With a broader goal of increasing public transport patronage, this paper has investigated and analysed the suitability of a conventional public bus route to be transformed into a transit corridor to support bus-based transit-oriented developments to occur in the outer suburban areas of metropolitan Adelaide. The paper also attempted to provide a framework for an alternative bus transit service for the corridor. The next step of the research would require a form of public consultation to have an understanding of the general public preferences towards public transportation, and particularly, their choice preferences for the proposed changes as discussed in this paper. This study has demonstrated that with support of an effective integrated transport and land use policy, a conventional arterial bus route, such as Main North Road, has the potential to be converted into a transit corridor with the requirement of limited modification. The concepts discussed in this paper seem to work within the context of metropolitan Adelaide and for the cities of similar characteristics.

# 7. References


ADAM, W., FLEMING, D. & PARSONS BRINCKERHOFF AUSTRALIA 2005. Effective bus-based transit oriented development. *Transit Oriented Development: Making It Happen, 2007, Perth, Western Australia, Australia.* Perth, Western Australia, Australia.

ALLAN, A., NAWAZ, M. & FIELKE, M. 2015. Transforming Adelaide into a city of networked TODs using buses: case study of the Adelaide OBahn. *Australasian Transport Research Forum.* Sydney, Australia.

BRAY, D. & SCRAFTON, D. 2000. The Adelaide O'Bahn: Ten Years On. *8th Joint Conference on Light Rail Transit.* Dallas, Texas, 2000: American Public Transportation Association and the Transportation Research Board.

CERVERO, R. 2000. Transport and land use: Key issues in metropolitan planning and smart growth. *University of California Transportation Center*.

CERVERO, R. & DAI, D. 2014. BRT TOD: Leveraging transit oriented development with bus rapid transit investments. *Transport Policy,* 36**,** 127-138.

CURRIE, G. 2005. Strengths and weakness of bus in relation to transit oriented development. *Transit Oriented Development–Making it Happen Conference.* Perth, Western Australia.

CURRIE, G. 2006. Bus rapid transit in Australasia: Performance, lessons learned and futures. *Journal of Public Transportation,* 9**,** 1.

CURRIE, G. 2014. Public transport progress and failure-Keeping up with growth in Australian cities. *Infrastructure for 21st Century Australian Cities: Papers from the ADC Forum National Infrastructure and Cities Summit March 2014.* Sydney, Australia: ADC Forum.

CURRIE, G. & DELBOSC, A. 2011. Understanding bus rapid transit route ridership drivers: An empirical study of Australian BRT systems. *Transport Policy,* 18**,** 755-764.

CURRIE, G. & LAI, H. 2008. Intermittent and dynamic transit lanes: Melbourne, Australia, experience. *Transportation Research Record: Journal of the Transportation Research Board***,** 49-56.

DEVNEY, J. 2011. Changing Perceptions of the Bus with Branded Services. *34th Australasian Transport Research Forum (ATRF).* Adelaide, Australia.

HENSHER, D. A. & GOLOB, T. F. 2008. Bus rapid transit systems: a comparative assessment. *Transportation,* 35**,** 501-518.

HO, C. & MULLEY, C. 2014. Metrobuses in Sydney: How high capacity and high frequency services are benefiting the Metropolitan fringe. *Research in Transportation Economics,* 48**,** 339-348.

JIANG, Y., CHRISTOPHER ZEGRAS, P. & MEHNDIRATTA, S. 2012. Walk the line: station context, corridor type and bus rapid transit walk access in Jinan, China. *Journal of Transport Geography,* 20**,** 1-14.

KEPAPTSOGLOU, K. & KARLAFTIS, M. 2009. Transit Route Network Design Problem: Review. *Journal of Transportation Engineering,* 135**,** 491-505.

LEVINSON, H. S., ZIMMERMAN, S., CLINGER, J. & RUTHERFORD, G. S. 2002. Bus rapid transit: An overview. *Journal of Public Transportation,* 5**,** 1.

LEVINSON, H. S., ZIMMERMAN, S., CLINGER, J., RUTHERFORD, S., SMITH, R. L., CRACKNELL, J. & SOBERMAN, R. 2003. *Bus rapid transit*, Transportation Research Board.

PLANNING AND TRANSPORT RESEARCH CENTRE - PATREC 2005. Transit-oriented development in Western Australia: Attitudes, obstacles, and opportunities.

ROSE, J., MULLEY, C., TSAI, C.-H. P. & HENSHER, D. 2013. Will bus travellers walk further for a more frequent service? A Stated preference investigation. *Australasian Transport Research Forum (ATRF), 36th, 2013, Brisbane, Queensland, Australia.*

TAYLOR, M. A. P., HOLYOAK, N. & MENG, L. 2011. Increasing the patronage of Adelaide's Northern Rail Corridor. *Australian Transport Research Forum* Adelaide.

THE GOVERNMENT OF SOUTH AUSTRALIA. 2014. *"New trams, trains and buses"* [Online]. Available: https://www.sa.gov.au/topics/transport-travel-and-motoring/public-transport-and-travel/new-trams-trains-and-buses [Accessed 29 May 2014].

THE GOVERNMENT OF SOUTH AUSTRALIA. 2015. *The Integrated Transport and Land Use Plan, July 2015* [Online]. Available: http://www.transportplan.sa.gov.au/ [Accessed 23 December 2015].

THE GOVERNMENT OF SOUTH AUSTRALIA. 2016. *South Australian Government Data Directory* [Online]. Available: http://data.sa.gov.au/data/dataset?organization=department-of-planning-transport-and-infrastructure&groups=transport-travel-and-motoring [Accessed 5 July 2016].

THE GOVERNMENT OF SOUTH AUSTRALIA. 2017. *Adelaide Metro Bus Timetables* [Online]. Available: https://www.adelaidemetro.com.au/ [Accessed 28th June 2017 2017].

WRIGHT, L. & HOOK, W. 2007. *Bus Rapid Transit Planning Guide* [Online]. Institute for Transportation and Development Policy, New York. Available: https://www.itdp.org/publication/brt-planning-guide-english/ [Accessed 17 April 2017].