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Bus based transit oriented development (BTOD): Opportunities and challenges for low density, car dependent Australian cities

Munshi Nawaz[1], Sekhar Somenahalli[1],and Andrew Allan[2]

[1]School of Natural and Built Environments, University of South Australia, Mawson Lakes, SA 5095.

[2]School of Art, Architecture and Design, University of South Australia, Adelaide, SA 5000.

Email for correspondence: munshi.nawaz@mymail.unisa.edu.au

Abstract

Over the decades, public transportation was less focused on overall, holistic and integrated town planning designs and has not coped with the rapid pace of car centric low density developments. Transit Oriented Development (TOD) principles are expected to substantially contribute towards achieving accessible, affordable and comfortable public transport services for low density Australian communities.

From the point of view of comparative infrastructure development, timeframe and costs, bus based systems (BTODs) seem to be more appropriate than rail based systems (RTODs) in the Australian context, where bus based transport routes already play a significant role in the overall transportation system of cities. The transit passenger densities in the corridor catchments of low-medium density suburban environments is better suited to buses than light or heavy rail transit which require large commuter volumes. Buses also offer greater flexibility supporting feeder services in addition to serving trunk routes and potentially has a much greater reach beyond high passenger density transit corridors.

This paper investigates and formulates policies on how bus based transits can be used in achieving transit oriented developments through successfully implementing TOD principles with bus transit within the context of Australian cities. This paper will analyse existing land use and demographic data along a bus route on a suburban arterial road to identify the suitability of land for higher density developments that would potentially make the transformation of a bus route into a transit corridor viable. The selection criteria in undertaking land suitability analysis to achieve 'concentrated densities around the nodes' will also be discussed. The findings of this research will be of value in developing a methodology for undertaking an extensive land use analysis for the purposes of developing a BTOD model to transition low density car dependent Australian cities towards more transit oriented and environmentally sustainable urban environments.

Key words: BTODs, Land suitability analysis.

1. Introduction

Urban sprawl is considered to be one of the key reasons behind the significant increase in private car ownership. The International Energy Agency (IEA) estimated that between 2000 and 2050, worldwide there will be a 1.7% annual increase in cars as a mode of transport. The IEA also found that the use of transit modes has decreased due to low density development and greater convenience of private vehicles (Shaheen and Lipman, 2007). During the period when cars were becoming more affordable to the general public, up until the 1960s, cities around the world developed to cater to cars as a solution to cities' transportation needs, which led to the development of planning policies that directly and indirectly facilitated sprawl. Although decentralization policies initially helped in reducing crowding in inner city industrial zones, social, economic and environmental impacts soon emerged as a new challenge to further advancement with town planning principles (Belzer and Autler, 2002). Public transportation was given less of a focus in overall town planning designs and has not coped with the pace of the rapid developments of the ever expanding outer suburbs, away from the places of regular community services and facilities.

An alternative approach to reducing dependency on private vehicles would be to offer policies and strategies that result in the formulation of sustainable transport and land use plans, which would encourage the wider population to place greater reliance on public transport. To this end, concepts of "smart growth" and "transit villages" have been advocated by experts for some decades now. The concept of Transit Oriented Development (TOD) has evolved from similar principles and is expected to substantially contribute to accessible, affordable and comfortable public transport services to the community if effectively implemented. So far, there is no standardized definition of a TOD, with many researchers having defined TOD differently. Higgins and Kanaroglou (2016) have defined TOD as a concept that "refers to dense, mixed-use and pedestrian friendly development oriented to rapid transit". A TOD can also be defined as a mixed use community within an average radius distance of 400m to transit stops and core commercial areas. The basic principle of TOD can be explained as the design of a mixed use relatively higher density development emphasizing pedestrian accessibility to a major transit route and reinforcing the use of public transportation (Parker, 2002).

This paper aims to conduct an investigation of the elements that make a transit oriented development successful, i.e. in terms of success in attracting public transport ridership. Generally, rail is considered to be the key transit during development of relevant TOD policies. This paper will look into the potential of buses as public transit in providing more accessibility to communities, facilitating higher density residential / mixed use areas along the corridor whilst requiring lower establishment and operational costs in comparison with a rail based transit.

Generally, the study will undertake analysis of some preliminary parameters that would enable the development of strategies, issues and policy directions for bus TODs in the context of low density cities. This paper will also discuss constraints and opportunities of BTODs in comparison with RTODs. The outcome of the study is expected to help the development of a new approach to measure the impacts of accessibility on TODs, i.e. to examine if bus based transit corridors can increase accessibility to transit.

2. Constraints and opportunities of bus based Transit Oriented Development (BTODs)

Many experts have focused on rail based TOD (RTOD), in combination with other modes of local transport options. This is mostly because of the confidence in future investment in development that a rail based TOD can offer to a community. Such confidence then translates into the changes in local planning policies and property values that facilitate the development of TOD communities along a corridor (Currie, 2005). However, thus far, no concrete evidence established that reflects a definite public preferences for a rail based transit over a bus service (Hensher et al., 2015). Even when there was a bias found towards a rail based system within the community, public preferences were found to be motivated by rational considerations of the realistic factors, such as: available government funds; comparing services of alternative options; the estimated project completion time frame etc. (Hensher et al., 2015).

As observed in most capital cities in Australia, where most outer suburban areas are found to be located beyond the maximum service coverage (i.e. 1km or more) of the rail network, attracting people to shift away from their usual dependency on private cars would be difficult because of the inadequacy of a public transportation system in those areas that corresponds to less accessibility to these services (in terms of walking distances, frequency of services etc.) compared to the freedom and flexibility that private vehicle ownership offers. An integration of a preferred rail service with intermediate public transport modes linked with active transport facilities (i.e. walking & cycling) can be considered as an alternative approach in addressing this issue (Allan, 2011). Bus based transit oriented developments (BTODs) can therefore be a potential alternative to RTODs, as buses can provide the flexibility in serving car dependent outer communities, where rail may not be a viable option from planning, economic or political considerations. Cervero (2000) made similar suggestions that the development of public bus oriented transit corridors are more viable options for lower density outer suburban areas than is the case for rail. Ho and Mulley (2014) also suggest that traditional BRT style bus services are essential for the fringe areas of metropolitan cities (i.e. their study area was the fringe areas of metropolitan Sydney), where access to direct public transport routes (to the inner cities) are limited, thus causing the community to become dependent on private cars.

In comparing BTOD with RTOD, RTODs are widely accepted by the experts as longer term solutions, by means of capacity building, building public confidence etc. (Currie 2005). However, the costs associated with RTODs are significant, and in many economies, such an investment decision is very likely to be influenced by the prevailing political motivation. The success of RTOD in attracting a significant number of users is not a definite outcome either. Relevant costs can also be a significant concern as the current expansion of Metropolitan Adelaide's commuter railway network as proposed in the Planning Strategy for metropolitan Adelaide was costed at $2 billion resulting in a modest 4% increase in the number of transit users (Allan, 2011).

In terms of functionality and performance, Adam et al. (2005) have analysed built environment characteristics and travel behaviour in support of bus based transit oriented development. The study has carefully looked into the necessary infrastructure for supporting TODs and recommended a number of design recommendations (i.e. in terms of infrastructure design, service quality and frequency etc.) in order to increase accessibility. The authors suggested a multi-tier network design for achieving appropriate accessibility requirements. The drawback to this approach is that a large number of fossil fuel powered buses on the streets may result in having a greater footprint of CO_2 emission outcomes compared to that of a rail service, however, ever emerging hybrid and full electric technologies may effectively address this issue.

From the perspective of costs, it is also evident that the relative costs of improving an existing public bus service would be significantly lower and can be achieved within a relatively a shorter period of time. A recent study has found that BRTs can be developed at a much lower price of up to 4 to 20 times less than light rail transit (LRT) and 10 to 100 times less than metro-rail system (Cervero and Dai, 2014). The Fourth Assessment Report on Climate Change 2007 estimated that the costs of development of a BRT systems range between US$1-15 million/km, compared to an elevated rail system to cost US$50 million/km to over US$200 million/km for an underground metro rail system (Intergovernmental Panel on Climate Change - IPCC, 2007).

3. Potential of bus based TODs (BTODs) for low density, car dependent cities

As has been discussed above, rail based TODs may not be a viable option for many suburban areas, where the concepts of bus based transits and BTODs may play a significant role in achieving the same outcome as can be expected from RTODs. Cervero and Dai (2014) have closely looked into the concepts of TODs and examined how existing BRTs can be converted into transit corridors supporting TODs. Their work considered the disadvantages of a bus based TOD (i.e. low density, low speed and poor service frequency, lack of magnitude, unknown market implications etc.), as identified by Currie (2005), and discussed relevant solutions in their (Cervero and Dai, 2014) paper. Cervero and Dai (2014) developed design principles necessary to attain the required density and accessibility, and argued that these could be implemented effectively in the context of low density suburban areas of Australia.

Ho and Mulley (2014) completed a recent study of the introduction of Metrobus services in Sydney and analysed the impact of these services on Sydney's outer metropolitan areas. The Metrobus service was introduced alongside a pre-existing bus network in the metropolitan fringe areas of Sydney and this study has shown that the introduction of high frequency and high capacity Metrobus services has increased patronage in metropolitan fringe areas. Apart from the cities of Sydney and Melbourne, all other major Australian cities, including regional cities and towns, share a common characteristic of low density residential areas that has developed horizontally particularly outer areas. In contrast to Sydney and Melbourne, where rail based transit corridors are considered to be the dominant transport services, Brisbane, Perth and Adelaide have strengths in their bus networks and this is reflected in higher modal shares for buses over other forms of transit.

The South-East Busway of Brisbane is an example that gives us a unique opportunity in understanding the performances of a dedicated public transport corridor and of a traditional freeway in the Australian context. Analysis show that the carrying capacity of a busway lane (3,600 people per hour) is considerably higher than that of a typical freeway lane (2,400 people/ hour) (Department of Transport and Main Roads - Queensland, 2010). The South East Busway has not been designed based on the principles of TOD, rather the Busway policy appears to have been designed as a response to the future growth of south-east Brisbane (TRANSLink - Queensland, 2015). Nevertheless, the existing Brisbane Busway has demonstrated a performance outcome, in terms of capacity, connectivity, accessibility etc., which can be investigated further in the context of other metropolitan cities in Australia, including metropolitan Adelaide.

The Adelaide O-Bahn is a classic example of a successful service (Bray and Scrafton, 2000) that has scope for further investigation and identification of factors that may facilitate the transformation of the corridor adjacent areas into TODs; particularly at the locations of the Klemzig and Paradise interchanges (Allan et al., 2015).

In July 2015, the Government of South Australia released the Integrated Transport and Land Use Plan (ITLUP), which focused on improving Adelaide's public transportation system in terms of coordination, accessibility and minimising transport disadvantage across the metropolitan area. Given that approximately 80% of the public transit journeys in Adelaide are serviced by its existing bus network, the Plan recommended a number of bus based priority policies alongside the actions recommended for enhancement and expansion of the railway system and the road networks. The Plan (ITLUP) articulates the transport requirements implied in the 30 Year Plan for Greater Adelaide (30YPGA) and recommended a number of ways to redesign and modernise the existing bus network. With the availability of this policy background, this paper examines how a bus based transit corridor can support existing developed areas whilst facilitating new development and urban intensification at major transit nodes (i.e. through making TODs into a form of "super stops") (The Government of South Australia, 2015).

4. Methodology

For the development of Transit Oriented Developments in low density car centric cities, a functional public transport network (with interconnected routes) is essential to provide a range of desirable trip destinations along with the capacity to accommodate the growth of public transport patronage. A parallel requirement is the necessity of increasing density around nodes or transport interchanges that are suitable to be transformed into TODs (Allan and Fielke, 2015). In accordance with the TOD principles, this paper will investigate and analyse traditional public bus routes as an alternative to rail transit corridors and will identify and discuss variables that may influence the transition towards bus based TODs along a bus route transformed into a bus based transit corridor.

4.1 Selection of the study area and study route

As a low density car dependent city within the Australian context, Adelaide has extensive bus networks (i.e. the Integrated Transport and Land Use Plan 2015 - ITLUP estimates that the existing bus network supports around 80% of the public transport journeys), covering many distant residential suburbs that are connected to major local business centres and to the central business district. From a major transport connection point of view, Adelaide's northeastern region can be considered as very important as a number of major roads, railways and a dedicated bus corridor are situated within this region. The Adelaide O-Bahn, the northern rail corridor, major roads such as Main North Road, North-East Road etc. are located within this region in a north-south orientation. The Adelaide O-Bahn is a unique and extraordinarily successful public transit system, however the success of the O-Bahn would be difficult to replicate elsewhere within the metropolitan area because of the lack of undeveloped or vacant land for a transit corridor, the lack of public support on environmental concerns and a lack of political motivation. Therefore, this study has focused on a standard suburban bus route as a transit corridor for the purpose of identifying potential land which is suitable for the development of TODs and for supporting the performance of a future corridor. As a major thoroughfare, connecting the Adelaide CBD and the distant northern suburbs, Main North Road is taken as the study route for the purpose of this study.

Starting from North Adelaide, the first 21kms length of Main North Road was chosen as a study route for this analysis as this segment services a number of neighbourhoods, where residential use is dominant although along the road frontage commercial, retail and services predominate. The population and employment density was identified to be the highest within the road segment between Nottage Terrace and Grand Junction Road, while densities appear to be dispersed much more weakly along the northern segment of the corridor.

4.2 Land suitability Analysis

The development of successful TODs along any road corridor requires careful examination of firstly, the existing services and infrastructure; and secondly, it requires the analysis and identification of suitable parcels of land that may facilitate the development of future TODs. For this study, a land suitability analysis has been undertaken along Main North Road, which identified the most and least suitable locations for future TODs. The data used in this analysis was collected in 2007 from the then Department of Planning, South Australia.

In identifying the potential BTOD locations, four different parameters were selected for the purpose of the analysis of the suitability of any given parcel of land. The parameters were: (1) the proximity to Main North Road; (2) the proximity to the identified Nodes; (3) existing Land Use; and (4) the density of population. The attributes of these parameters were weighted according to their level of significance. A general scale of 1 to 5 was selected and the values were assigned against the elements of these parameters in accordance with their perceived influence on land developments. Value ‘5’ was assigned for the most suitable characteristics while ‘1’ was assigned for the least suitable. Table 1 represents the weighted values used for the analysis.

Table 1: List of input Weights

Level of Suitability	Weight
Least Suitable	1
Less suitable	2
Moderate (but potential)	3
Suitable	4
Most Suitable	5

The parameters were analysed concurrently in order to achieve independent outcomes/ findings. However, to determine the potential of a particular parcel of land for future TODs, all of these parameters were analysed independently by mapping for all land parcels in the corridor. All these parameters were then given independent weights based on the consideration of their significance and an aggregate outcome was then produced to determine their level of suitability for development intensification to assist in maximising the commuter catchment potential. A weighted overlay method was applied in this study, which demonstrated the level of suitability of land for TODs by way of showing most and least suitable land available based on the calculation of independent level of significance (expressed in percentage as input) of each of the parameters.

5. Analysis and Results

The techniques that was used to analyse the selected parameters and their corresponding suitability are briefly described as follows:

5.1 The proximity to Main North Road and to the nodes

The proximity measures were set using the centreline of Main North Road. A set of buffers was created based on the distances from the road. The parcels of land located within a distance of 400 metres were considered as the ‘most suitable’ land whilst any land located beyond 1000m was considered least suitable. Corresponding significance weighting values (i.e. from 5 to 1 respectively) were given in the GIS attribute table under the field name of “weight”.

This Buffer shape file was then converted into a raster, where the analysis resulted in the display of colours representing a level of suitability based on the values put in the GIS attribute table field “weight”. A similar process was followed in the identification of the suitability of land based on the parameter of the proximity to the nodes. Figure 1 illustrates the analysis and the outcomes from mapping these parameters.

Figure 1: Site suitability maps- the Proximity to Main North Road and to the nodes

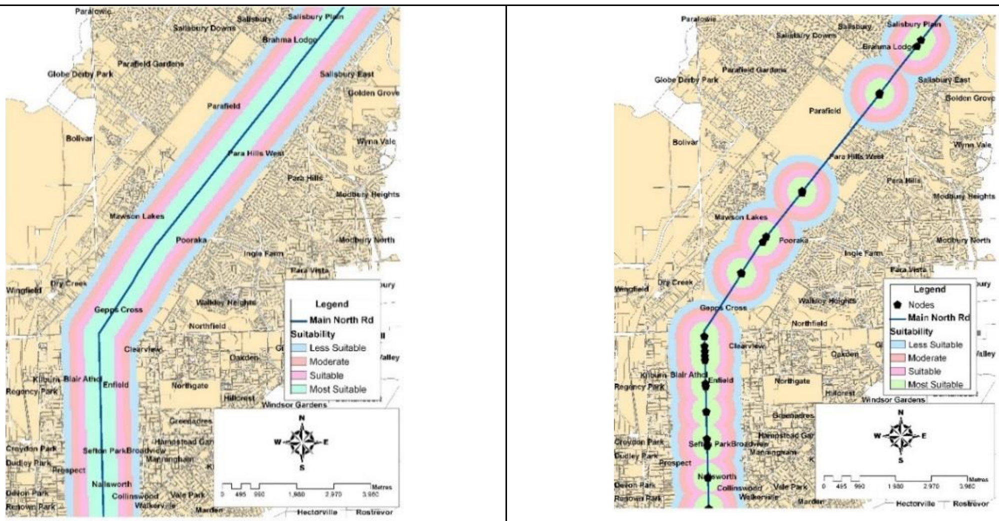

Fig 1.1 Site suitability outcomes for Main North Road

Fig 1.2 Site suitability outcomes for identified nodes

5.2 Existing Land Use

Different types of land uses were assigned with different weights based on their significance to future development. 'Vacant' and 'vacant residential' types were given the highest value (i.e. 5 for most suitable) for their potential to be developed with TOD supportive designs. Although the existing zoning requirements of the local Councils' development plans restrain the development potential of this land, careful rezoning of land can address this issue. Considering the potential for development that higher density residential and commercial zonings provides, the second highest value (i.e. 4) was allocated to these land uses. The land uses (i.e. such as 'education', 'recreation' etc.) that reflect a rigid characteristics with no potential for future changes for social or amenity reasons were given the lowest value of 1 for being the least suitable options.

Once the appropriate weights were allocated, the land use layer (in ArcGIS) was converted into a raster, similar to the procedure applied for the first two parameters. Figure 2.1 illustrates the result of this analysis. The maps show that a major portion of the 'most suitable' land was located between the segment of Grand Junction Road and Parafield airport. This is because of the availability of vacant land along this segment of Main North Road. A vast area was found 'suitable' along the southern segment of Main North Road because of the predominant use of land for retail commercial residential purposes.

5.3 Density of population

A higher level of residential density within walking distance of transit stations is considered desirable for a successful transit oriented development in terms of having a sufficient commuter catchment to support a sustainable transit system (Cervero and Kockelman, 1997). The population density of respective areas was calculated using ArcGIS (i.e. in the Attribute Table) and was categorised into five (5) groups, i.e. 0-13 persons/ hectare, 14-25 persons/ hectare, 26-38 persons/ hectare, 39-50 persons/ hectare and 51-63 persons/ hectare. Newman (2005) considers that a minimum density of 35 residences and jobs per hectare is required to provide a minimum range of amenity and services, and is a pre-requisite for a public transport system to be viable. The density group of ‘14 to 25 persons/ hectare’ was considered as the best prospect for development intensification (hence the weighting of 5 was awarded), as higher density developments may easily be achieved to reach the preferred density level of 35 persons/ hectare compared to the areas where density was less than 10 persons/hectare. The density group of ‘26-38 persons/ hectare’ was considered to be the next most promising area for potential development and a weight of 4 was allocated. The density groups of ‘39-50 persons/ hectare’ and ‘51-63 persons/ hectare’ were considered to be of very low importance, and given the low density development trend in Adelaide, densities of those groups either appear in very small areas or do not appear at all. These groups were given values of 2 and 1 respectively.

The density layer with the allocated weights mentioned above were then converted into a raster image to obtain the final suitability results. Figure 2.2 shows that almost all lands located along the southern segment of Main North Road were found to be ‘most suitable’, while the suitability of the northern segment of the road corridor was found to be only ‘moderately’ suitable.

Figure 2: Site suitability maps – Land Use and Density of population

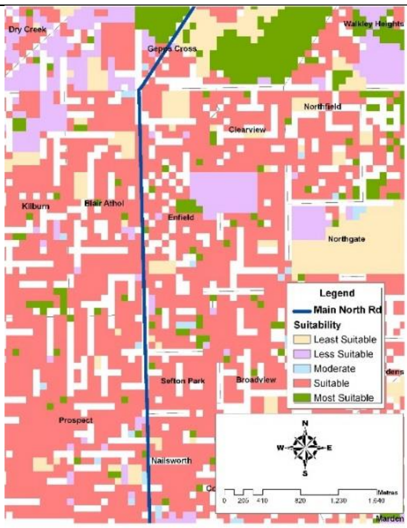

Fig 2.1 Site Suitability Maps from land use analysis (Southern segment of Main North Road)

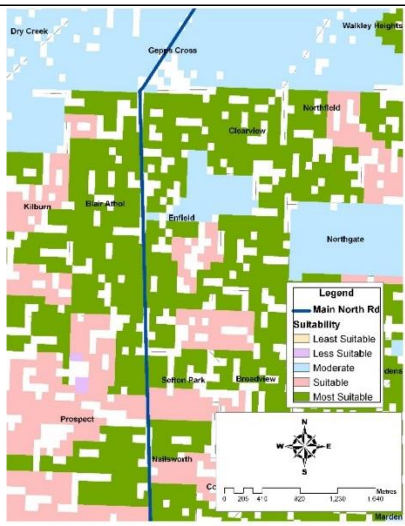

Fig 2.2 Site Suitability Maps from density analysis (Southern segment of Main North Road)

5.4 Weighted Overlay Method

This was the final stage of the site suitability analysis. A tool named 'Weighted Overlay' was used to determine the most appropriate locations. Based on the significance of the above parameters, final weights were allocated to each parameter to obtain a collective output. As four different parameters were used, each capable of determining land suitability independently, overall weights were assigned to each parameter based on their individual level of significance. In this instance, the level of significance was valued in terms of a percentage contribution. The contribution of each parameter were compared with one another. The 'existing land use' parameter was considered to have the highest contribution of 35% considering the fact that careful land use planning can be used to determine the most appropriate zoning, which assists in determining the required design and development outcomes for future TODs. Table 2 represents relative weights of the selected parameters.

Table 2: Weights Assigned to Overlay Parameters

Parameters	Weights (in %)
Land Use	35
Nodes (Accessibility)	30
Density	20
Road (Proximity)	15

The proximity to the Local Centres (Nodes) was considered to have the second highest contribution (30%) since the proximity to transit services is the first requirement in achieving successful transit oriented developments. Secondly, nodes located within or adjacent to the local or neighbourhood centres have an additional attribute of increased accessibility to services and facilities, which would be a key determinant for supporting TODs.

The result of the 'weighted overlay' of the four parameters is demonstrated in Figure 3. As a result of the complete analysis, the green spots in the maps represent the 'most suitable' land for the development of future TODs along Main North Road. This category of suitability is also dominated by the next category of 'suitable' land along the corridor. The result indicates that if Main North Road is considered to be a transit corridor then there is sufficient land available along the corridor for bus based transit oriented developments. Where a clustering of areas of greatest suitability occurs, transit oriented urban development could occur at its highest density. The spacing of transit nodes or stops, would however be influenced by the most efficient spacing of transit nodes or interchanges to ensure that bus services operate efficiently and at the highest practical route speed.

Figure 3: Land suitability analysis for BTODs

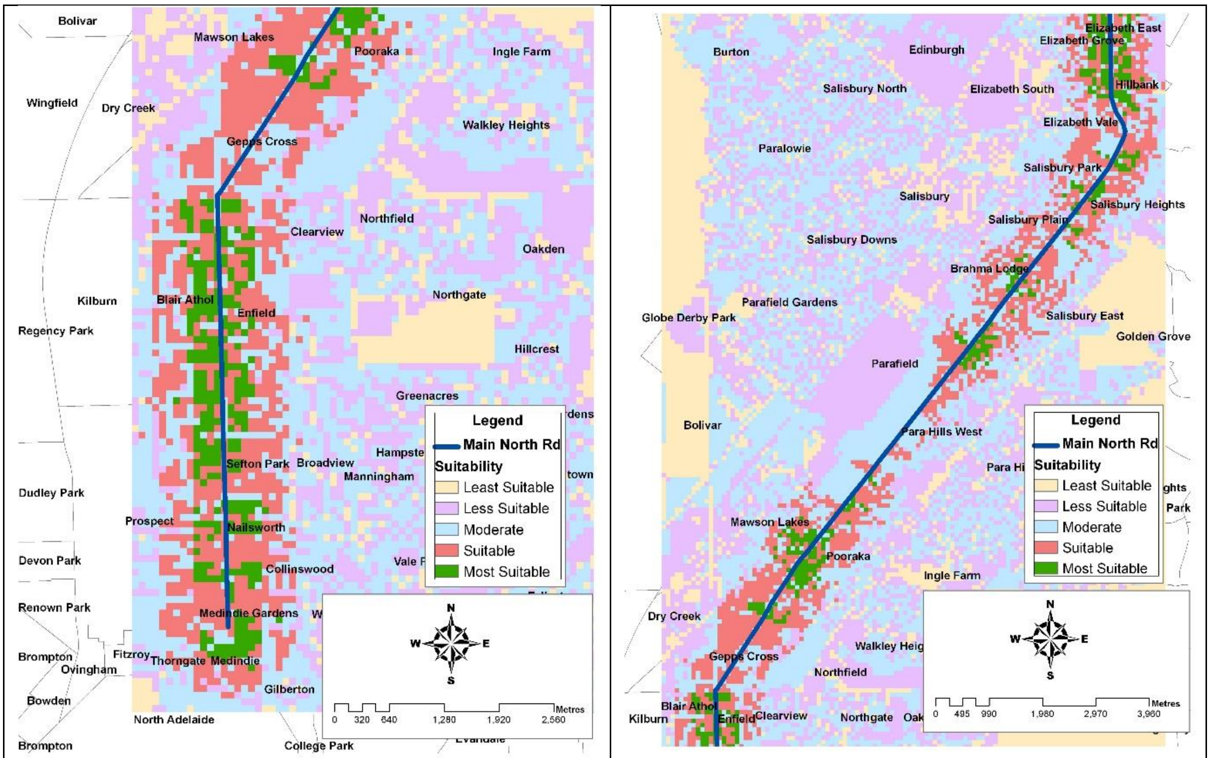

Fig 3.1 Suitability of land for TODs along Main North Road corridor (South)

Fig 3.2 Suitability of land for TODs along Main North Road corridor (North)

6. Discussion and Conclusion

This study focused on the investigation of the relevant variables of the transit oriented development concept within the context of what would make a successful bus based transit corridor and transit oriented developments, using Adelaide's Main North Road in Adelaide's northern suburbs as a case study. The parameters selected for the study and the adopted methodology demonstrate that appropriate land use policies would support bus based TODs along an established bus network servicing low density communities. With the above analysis, this paper demonstrates that there are ample opportunities available for a major bus route, such as, Main North Road, that can be transformed into a bus corridor, supporting a higher density of population and employment along the corridor than currently exists.

The Figure 3.1 shows a long stretch of the "most suitable" category land identified as a result of the analysis along the southern segment of the Main North Road corridor. For determination of more definite locations for future TODs, some additional parameters can be considered and can be included as part of further analysis. For example, all land within the 'commercial' zoning along the corridor does not reflect the same level of density of employment, and is therefore, very likely to represent varied level of significance (i.e. with varied corresponding weights) as discussed above. If ‘density of employment’ is considered as the fifth parameter, it is expected to demonstrate more concentrated areas with “most suitable” quality of land for TODs. It was also difficult to categorise the existing commercial allotments with parking facilities onsite for analytical purposes. This is because the availability of parking spaces is a form of amenity supporting existing commercial activities, and while these spaces can be considered as under-utilised land with the potential to be developed for higher density population and employment. The size and prices of existing properties, existing road and infrastructure etc. are some other potential parameters, which can be investigated further with similar techniques applied to obtain better results. Detailed spatial analysis along the corridor as discussed in this study would result in the identification of available land supporting higher ‘density’ and increased ‘diversity’ in the targeted areas.

“Design” (i.e. accessibility), as a TOD variable, is considered to be an important issue to be addressed in order to increase overall bus patronage. The functional modification of the bus route can be considered as the first design policy for any corridor development. The existing road width and route coverage of the Main North Road is considered to be one of the key opportunities for its transformation into a corridor. The development of a dedicated bus lane would be the first design consideration, along with other considerations such as: the provisioning of additional traffic lanes where achievable, accessible and safe bus stops etc. With proper marketing or branding of the TOD corridors and the services it provides, it is expected that a significant number of people can be attracted to public transit, and people’s attitudes may also change over time towards higher density living within TODs (Planning and Transport Research Centre - PATREC, 2005).

From the land use pattern analysis, it was found that most suburbs along Main North Road corridor are of low density (i.e. single storey bungalows or two storey units). The provisions within the existing development plans are partly responsible for reinforcing the general public’s overall preferences for low density car oriented housing. The introduction of the Integrated Transport and Land Use Plan (ITLUP)-2015 is a positive step forward from South Australia’s point of view, however, to achieve an effective land use planning outcome, amendments to the relevant provisions of local councils’ Development Plans are essential. Nominating location where the transit interchanges may occur, rezoning of land along the transit corridor to facilitate higher urban densities, mandating the traffic network planning with the inclusion of the design requirements of the road widenings/improvements to upgrade the bus transit corridors to allow efficient and high speed bus operations etc. are some of the key policy issues to be focused in amendments of the development plans. Investments would also be required in technology to allow improved coordination of bus services. These works involve a time consuming and costly exercise, and demand an extensive engagements and coordination efforts among the state authorities and relevant local councils (Newman, 2005).

There is a considerable challenge in convincing the general population to relinquish the freedom of using private modes of transport unless public transport options are presented to them as a genuine and compelling alternative. Further research on this project is expected to identify and quantify what can be achieved in increasing public transport patronage based around bus based transit within the context of a metropolitan Adelaide case study. Future research will provide a strong policy justification for politicians and for policy makers of the potential of bus based public transit as an affordable, efficient and functional investment option in local TODs that offers integrated solutions for land use, transportation and environmental policy outcomes.

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