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A Multi-Criteria Decision Analysis for selecting a bus-based transit corridor supporting transit-oriented developments (BTODs): an Australian case study

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Abstract

The outer suburban areas of most Australian cities consist of relatively low-density communities; Adelaide is no exception. The majority of the outer metropolitan suburban areas are not served by the conventional public rail networks. Although conventional bus services are available, the lack of service design and efficiency is an issue in attracting more patronage in these areas. Bus-based Transit Oriented Development (BTOD) principles provide an opportunity for these communities. The creation of major activity centres as major transport and land use hubs along future bus rapid transit corridors may attract more patronage by providing more accessible, affordable and comfortable bus services for these communities as an alternative to the rail service.

This study investigates five (5) potential bus routes along the northern expanding region of metropolitan Adelaide to select a corridor for a future bus transit service. A two-step method was adopted in estimating the suitability of the bus routes. As Step 1, nine (9) criteria/variables were selected considering their relevance to a potentially successful transit corridor. An equation was developed to quantify the results of the independent criterion analysis in comparable 'suitability scores'. As part of Step 2, a multi-criteria decision analysis (Analytical Hierarchy Process-AHP) was undertaken to address the inequality of importance/ weights of the criteria in the corridor selection process. A survey was undertaken to understand experts' opinions on the importance/ weights of the criteria and, subsequently were used in estimating the final suitability scores of the candidate corridors. Main North Road was found to be the most suitable corridor based on both the total and the average suitability score results.

Transport practitioners are expected to apply the two-step method in determining suitable bus transit corridors by investigating similar criteria using the comparable suitability scores, and finally, by considering their relative importance (weights) in the decision-making.

Keywords: Bus-based transit-oriented developments, bus rapid transit, suitability score, multi-criteria decision analysis.

1. Introduction

In most outer suburban areas in most capital cities in Australia, vast built-up areas are usually found in the middle of two adjacent transit corridors (mostly rail corridors). As a low density and car-dependent city in the Australian context, Adelaide has an extensive bus network connecting many outer suburbs of residential and mixed-use communities with the major local business centres and with the central business district (The Government of South Australia, 2014). However, the existing bus services appear to have either deteriorated in quality or have not expanded with the pace of high population growth (Currie, 2014). Integration of a preferred rail service with the intermediate public transport modes (i.e. feeder bus services) linked with active transport modes (i.e. walking & cycling) was also considered as an ideal approach in providing access to farther suburban areas (Allan, 2011).

In the context of metropolitan Adelaide, northern suburban areas, such as, Pooraka, Salisbury East, Ingle Farm, Elizabeth Downs, Modbury Heights, Valley Views, Parafield Gardens Craigmore etc. are located beyond the walking distance of the existing Adelaide Northern Rail Corridor (Meng, 2013) and from the Adelaide OBahn and are currently serviced only by conventional public bus services (Cervero, 2000). The concept of bus-based transit-oriented developments (BTODs) along developed bus transit corridors was considered to be a viable option for these lower density outer suburban areas. Ho and Mulley (2014) also suggested that traditional bus rapid transit (BRT) style bus services would be essential for the fringe areas of metropolitan cities, where access to direct public transport routes (to the inner cities) was limited. This lack of access was identified to be one of the key causes leading these communities to become dependent on private cars. The success of a BRT service is however highly dependent upon a number of social and qualitative attributes such as; pedestrian accessibility to the stations/ bus stops, properly connected networks of pedestrian and cycling pathways, safety and security locally and when using the transit, the frequency of services during the weekdays and during weekends, etc. (Taylor et al., 2011). The increased frequency of services is another attribute that BRTs can offer, which may also attract more people making additional efforts catching such a service (Rose et al., 2013).

By analysing the catchment of the existing rail (and OBahn) corridors within Adelaide's north-eastern region, it was observed that the areas between the rail and OBahn corridors are mostly built-up areas. The majority of these areas are located at least 1.0km away from either of the corridors. Strategically, Adelaide OBahn is considered to be highly significant (Allan and Fielke, 2015) for the northern suburban areas. Although, the OBahn was seen as a great success with a 58.8% increase in trips in the first five years of its operation (Bray and Scrafton, 2000), the success was considered as mostly contributed from the share of "choice" passengers using the services for its unique characteristics as a guided busway (Currie, 2006). Nevertheless, a similar service/ infrastructure would be very unlikely to be replicated elsewhere within the metropolitan area for several practical reasons such as the unavailability of similar linear parkland, lack of public support on environmental concerns, and for the lack of political motivation.

BRT technologies provide improved service design compared to the conventional bus service, which facilitates improved ridership (Currie and Delbosc, 2011). Based on the literature as discussed above, this study was undertaken as part of a broader research with a key objective of understanding if cost-effective BRT services would be achievable using conventional roadways, which could also support TODs in metropolitan Adelaide's context. The existing conventional bus routes were given consideration for transformation into Bus Rapid Transit corridors that would not only provide rail-like reliable high-frequency services to the communities but also would demonstrate the potential to be linked to appropriate land use planning.

This study investigated the major arterial road routes of Adelaide's north-eastern region and estimated their capacity to be transformed into bus rapid transit corridors. Along with the physical qualities needed, the study also investigated the land use and demographic data of the road-adjoining areas so that the development potential for these areas could be considered in the corridor selection process. The land use and demographic data analysis provided a better understanding of the candidate corridors' quality to support a higher density of employment and population growth required for long-term demand-driven viability of the bus transit corridor. Both approaches collectively provided quantitative results representing the suitability of the selected candidate corridors.

The research has investigated and identified the key selection criteria for a road (or a route) to be selected as a bus-based transit corridor. The adopted methodology has been outlined in Section 2 of this paper. Five (5) initial candidate routes were identified and were assessed against nine (9) selection criteria/variables. As Step 1 of the study, as presented in Section 3, an equation was developed to estimate individual "suitability scores" for each variable, which subsequently provided for the suitability scores of the initial candidate corridors. As part of Step 2, a multi-criteria decision analysis (Analytical Hierarchy Process- AHP) was undertaken to acquire relative weights/ importance of the nine (9) selected criteria, which has been described in Section 4 of this paper. This section also details the expert opinion survey data and analysis. Section 5 refers to the final results of the overall analysis, and provides a brief discussion and conclusion. It is expected that similar methods can be applied to determine suitable bus transit corridors for other major cities of Australia, such as the lower density outer suburban areas of Melbourne and Sydney.

2. Methodology

2.1 Selection of the initial candidate corridors

In major cities, the selection of corridors for bus rapid transit (BRT) service was not found to be a straightforward process. Beyond the key attribute of a route's capacity to accommodate the frequent peak traffic, there are many other factors involved that require methodical screening and evaluation in the selection of the BRT corridors (McNamara et al., 2006). McNamara et al. (2006) used the 'Harvey Ball' method for evaluating and shortlisting 80 initially selected candidate corridors into 36. They identified four key service-related benefits and compared the outcomes with BRT compatibility ratings of the selected 36 routes, which resulted in the selection of the final 15 corridors. In selection of transit corridors, the Growing Transit Communities Plan 2015 of Oregon-USA took an approach of estimation of scoring of five selected attributes (e.g. residential density, opportunity, equity, access and mixed-use land patterns) and shortlisted by selecting the highest scoring candidate corridors for their further research (Portland Bureau of Transportation -PBOT, 2015). The Center for Urban Transportation Research - CUTR (2004) undertook a study for the Miami-Dade Metropolitan Planning Organisation, where the 'percentage of the best' method was used to rank all candidate corridors against five selected attributes such as, riders per mile, total number of residents and employment within ½ mile buffer, household with zero auto ownership, household income, and overall transit potential. The analysis helped CUTR to shortlist the total number of candidate corridors into eleven (11) for further analysis. This study adopted a mixed approach with an additional recognition of the non-equal importance of the variables (addressed by AHP methods).

Considering the importance of the northern region of metropolitan Adelaide, this research investigated the suitability of an existing arterial road network between the Adelaide northern rail corridor and Adelaide OBahn. The key consideration was to select an arterial route with suitability to be transformed into a BRT corridor (preferably with a dedicated bus-lane). Five (5) initial candidate routes with such observed qualities were identified and assessed against nine (9) selection criteria/variables.

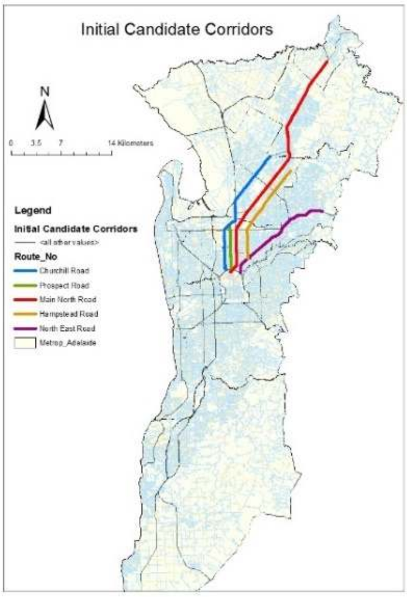
Table 1 lists the selected candidate corridors, while the geographic location of the routes is presented in Maps 1.1 and 1.2.

Table 1: Selected routes for suitability analysis

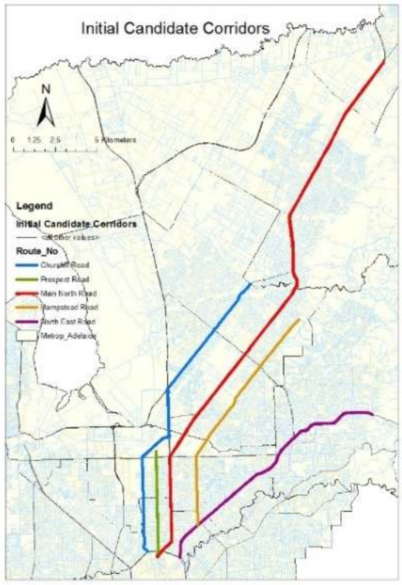
No.	Selected Initial Candidate Routes	Preferred Name (as referred to in this study)
1	Torrens Road (part) – Churchill Road – Cavan Road – Port Wakefield Road (part) – Salisbury Highway (part)	"Churchill Road"
2	Prospect Road	"Prospect Road"
3	Main North Road	"Main North Road"
4	North East Road (part)- Hampstead Road- Briens Road- Bridge Road	"Hampstead Road"
5	North East Road	"North East Road"

In the selection of the candidate corridors, one of the key focuses was the corridor's existing physical capacity to allow for dedicated bus lanes with minimum infrastructure costs required and causing minimum traffic disruptions. The candidate routes contained full or part of existing bus routes and shared similar characteristics closer to the Adelaide CBD, such as lanes for shared traffic, streetscape characters, activities on adjoining land, etc. Farther from the CBD, some routes were found providing services to existing residential communities (in varied capacity), while others adjoined predominant industrial or commercial land use activities. The routes were however different in physical characteristics, such as; carriageway width, BRT supportive existing infrastructures, etc.

Map 1.1: Initial Candidate Corridors in the context of Metropolitan Adelaide



Map 1.2: Initial Candidate Corridors (zoomed in)



2.2 Suitability analysis of the candidate corridors

In the context of the study, one key indicator of a suitable route was its capacity to be developed with homogeneous bus transit corridor infrastructure along its entire length as a transit corridor. However, in practice, most of these roadways were observed to have shared carriageways for buses and offered limited opportunities for transformation into transit corridors.

In determining the overall suitability of the selected candidate corridors, this study adopted a two-stage analytical approach, which was:

1) Estimation of independent "suitability scores" for each of the candidate corridors on the basis of the perceived significance of each identified variables/criteria, and
2) Undertaking a multi-criteria decision analysis to estimate the relative weights of the selected criteria, assuming that the selected criteria were not equally important in the corridor selection process.

2.2.1 Selection of corridor attributes / criteria

Nine (9) criteria/ variables were selected for this study for quantitative analysis of the candidate corridors. These criteria were selected from the considerations of- (1) the physical capacity of the routes, (2) the trip generating existing and potential future development and services along the corridors, and (3) the corridor-adjoining demography representing existing or future demand.

The list of criteria/ variables and the related assumptions are as below:

1) **Route Length –** A longer length might imply coverage of a broader catchment of both residential suburbs and employment hubs. As no literature was found suggesting a recommended length for a BRT corridor, a range up to 25km was selected for this study consistent with the candidate corridors. The Main Road data of the metropolitan Adelaide region was obtained from the South Australian government data directory (The Government of South Australia, 2016).
2) **Trip generating existing services –** More available services along a corridor would likely represent more trips generated from employment, shopping, education, etc. and thus, might represent a greater share of bus users. The relevant existing services data were collected by way of virtual observations of the candidate corridors using Google Streetview.
3) **Existing carriageway width –** One of the key considerations of this analysis was to select a route, where bulk of the existing infrastructure could be utilised with the minimum resulting impact on the existing traffic condition, and also, where the necessity of further road improvements or modification works would be minimal.

   A route with a longer length of sufficient road-width was considered indicative of its capacity to accommodate dedicated bus lanes, ideally required for a BRT (Wright and Hook, 2007). Not having the required road-width could be considered as a significant constraint of a roadway for BRT, regardless of its higher scores in other qualities.
4) **Existing population densities –** The density of urban development was considered to have a significant influence on ridership (Currie and Delbosc, 2011). For transit-oriented developments, a minimum density of 35 residences and jobs per hectare was considered to be required to support a viable public transport system (i.e. Rail) (Newman, 2005).

   It was assumed that the corridor with a higher density of population would provide for a higher number of public transport patronage and would, therefore, should qualify for higher suitability scores. The density of population (using Census 2011 data, Australia) within a 500-metre buffer was produced using ArcGIS as shown in Map 2.
5) **Dwellings with no cars –** The high level of car ownership in communities were found to have a correlation with the reduced number of route level ridership (Currie and Delbosc, 2011).

For the purpose of this analysis, it was assumed that the corridor (among the five selected corridors) with the highest density of dwellings (with no cars) would have a higher potential to provide for a higher number of public transport patronage and thus would qualify for a higher suitability score.

6) **Existing bus users (potential future bus users) –** It was also assumed that the corridor (among the five candidate corridors) with the higher density of existing bus users would represent a higher number of future public bus patronage.

   From the Census 2011 (Australia), four categories of the existing bus users were amalgamated to achieve the total number of potential future bus users, which were: 1) the total number of persons using buses only, 2) the total number of persons using cars as passengers only, 3) the number of persons using two methods, i.e. cars as passengers and buses, and 4) the number of persons using two methods, i.e. buses and other methods.

7) **Existing employed population density –** It was assumed that the number of the employed population located along the candidate corridors would be positively proportional to the number of future public bus patronage given that an improved service would be provided. The assumption acknowledges that the travel behaviour of the employed population would largely be dependent upon their types of employment, e.g. many would have to use either work or trade vehicles.

8) **The density of school students –** School students, who used buses were assumed to continue using public transport in their adulthood. This variable was also not considered as a strong decision-making factor given the uncertainty it presents related to the students chosen future career paths, relocation for higher studies, the desire to own personal cars, etc.

9) **Availability of vacant land –** Although all land use categories had the potential to be (re)developed in the future to generate higher population and employment densities along the candidate corridors, the category of "vacant land" was considered to be the most dominant of all for their potential to developed supporting future growth.

   From an available land-use dataset, all subcategories of "urban vacant land" along with "vacant offices" and "vacant shops" were collectively considered to estimate the total amount of "vacant land" available along the corridors within 500 metres.

2.2.2 Corridor suitability analysis

The above-listed selection criteria were weighed against a suitability scale (of 1 for "least suitable" to 5 for "most suitable") to determine the most suitable corridors for this study. For the purpose of maintaining consistency in the estimation of the suitability, all relevant attributes of the identified criteria were categorised in five (5) general classes as are represented in Table 2.

Table 2: Categories of the suitability criteria

Suitability criterion	Suitability Value
Least suitable	1
Less suitable	2
Moderately suitable	3
Suitable	4
Most suitable	5

As the types and forms of attributes of the selected criteria were different, so were their representative measurement unit values. While the length of the corridor was estimated in kilometres (in distance), road widths were measured with the number of carriageway lanes. All criteria representing demographic data analysis required the total counts of the census local statistical areas with the level of densities per hectares of land. The availability of vacant land along the candidate corridors was represented by land area (in hectares).

This research developed an equation (thus a methodology) to calculate "suitability scores" for the variables. This score was designed to represent a numerical value, with no associated measurement units attached, and could be derived from any of the above measurement units explained above. The suitability score provided for a common unit for comparison of the independent variables and facilitated the final decision-making from quantitative values/ scores. The formula developed for the purpose of this analysis is as follows:

Suitability Score $(S) = (n_1 \times v_j) + (n_2 \times v_j) + (n_3 \times v_j) + \dots \dots \dots \quad \dots .. (i)$

Where,

n_1, n_2, n_3 .. are the relevant variables under the selected criteria, such as distance, area, the number of census statistical areas (SA1) representing similar attributes, etc.

"v_j" represents the respective suitability value of the variables (i.e. n_1, n_2, n_3, .., etc.), i.e. values 1 to 5 represented the least to the most suitable attributes respectively.

2.3 Multi-Criteria Decision Analysis

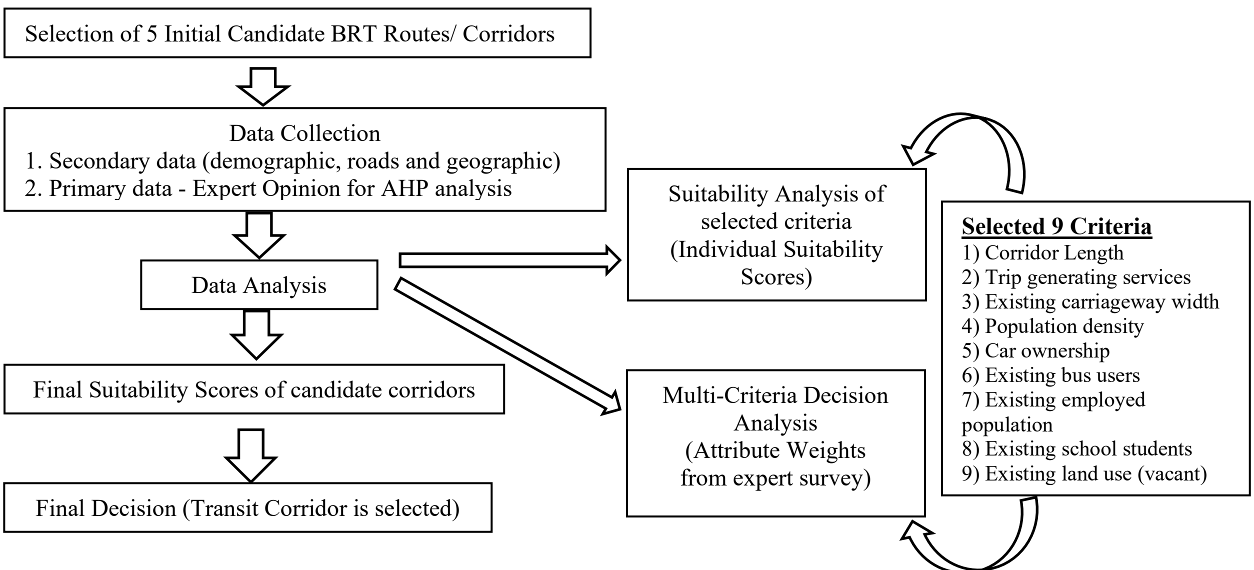
All nine criteria were recognised not to have equal importance/ influence in determining the suitability of a corridor. A multi-criteria decision analysis was therefore undertaken to determine their overall weights in calculating the final suitability scores of the candidate corridors.

A questionnaire survey was undertaken to collect experts' opinions on the pair-wise relationships of the criteria. Using the Analytical Hierarchy Process (AHP), the pair-wise comparison data were then transformed into the final relative weights of each of the selected criterion/variable.

The survey was approved by the University of South Australia's (Adelaide, Australia) Human Research Ethics Committee. The Ethics Protocol number is 201849. The details of the survey and the survey-results are discussed in section 4 of the paper.

The following diagram represents a summary of the transit corridor selection method as adopted, where nine criteria were investigated individually as step-1, and their individual weights/importance were compared based on experts' opinion.

Diagram 1: Transit corridor selection method



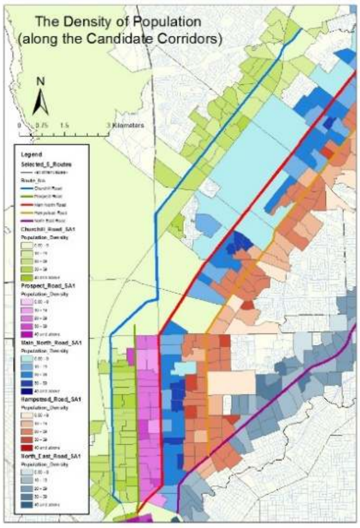
3. Corridor suitability analysis and results

All socio-demographic and the land use analysis are represented in Maps 2-7.

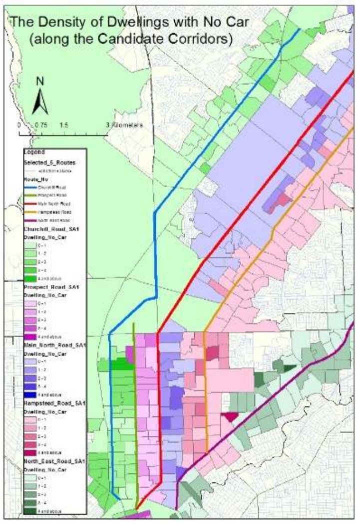
The full corridor suitability analysis has been summarised and presented in Table 3. The table demonstrates the method of how the corresponding suitability attributes, parameters, values were assigned for each of the selected criterion and, of how the 'suitability scores' for each criterion were calculated.

Table 4 represents a summary of the Suitability Scores of all candidate corridors estimated for each of the selected criteria.

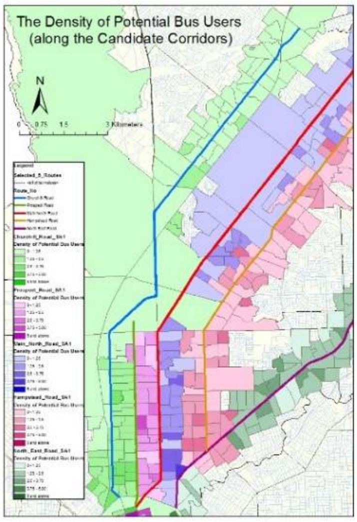
Map 2: Density of Population



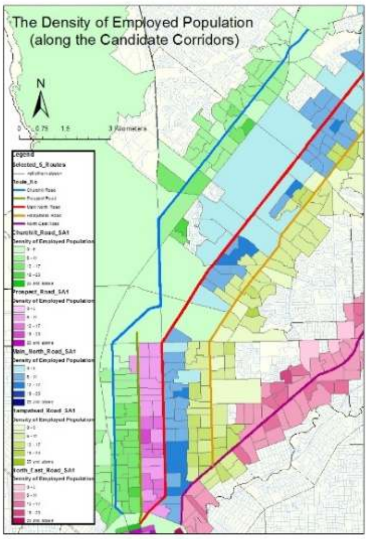
Map 3: Density of dwellings with no cars



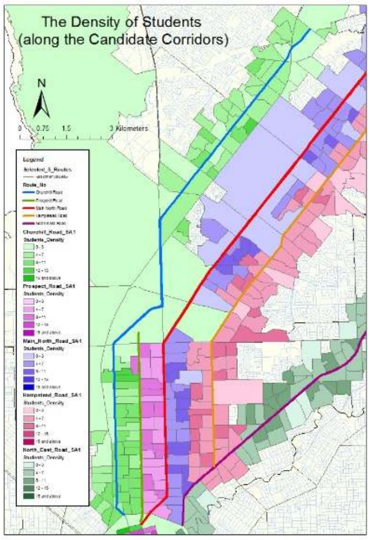
Map 4: Density of existing (potential future) bus users



Map 5: Density of the employed population



Map 6: Density of students



Map 7: Existing vacant land parcels

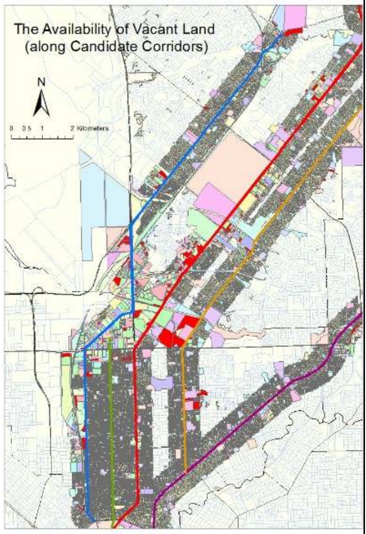


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Table 3: Estimation of independent suitability scores of the candidate corridors against the selected criteria and the corresponding suitability attributes, parameters, and values.

Selection Criteria	Selected Routes	Suitability Attributes, Parameters, and Classification: Least suitable (1)		Less suitable (2)			Moderately suitable (3)			Suitable (4)			Most suitable (5)	Total number of SA1s	Suitability score	Avg. Score
1. Route Length (Kilometres)		**Up to 8kms**		**8 – 12kms**			**12 - 16kms**			**16– 20kms**			**20kms and +**			
	Churchill Road	-		-			-			18.59			-		74.36	
	Prospect Road	5.94		-			-			-			-		5.94	
	Main North Road	-		-			-			-			33.5		**167.5**	
	Hampstead Road	-		-			-			16.67			-		66.68	
	North-East Road	-		-			15.70			-			-		47.1	
2. Trip generating existing services (Number of premises)		Local shops, Grocery & butcher, deli/ café/ pubs	Primary schools	Motor repair centres	Display Showrooms	Industrial outlets	Commercial & other offices	The cluster of shops/ Mini shopping centres	Major retails	Secondary schools	Medical centres/ pharmacy	TAFE & Tertiary institutions	Major shopping centres			
	Churchill Road	9	2	4	14	12	12	4	5	3	3	0	2		168	9.0
	Prospect Road	24	3	2	12	3	18	22	1	1	3	0	0		200	**33.67**
	Main North Road	20	6	14	50	7	11	22	16	4	8	2	5		396	11.8
	Hampstead Road	20	1	6	7	1	8	5	0	1	6	0	1		121	7.25
	North-East Road	60	0	12	35	0	33	19	15	0	11	0	3		**414**	26.37
3. Existing carriageway width (Number of carriageway lanes-Km)		**2 Lanes**		**3 Lanes**			**4 Lanes**			**5 Lanes**			**6 Lanes**			
	Churchill Road	2.3		0			12.9			0.51			2.85		57.29	3.08
	Prospect Road	5.6		0			0			0			0.35		7.35	1.24
	Main North Road	0		0			2.16			1.38			30.1		**162.5**	**4.85**
	Hampstead Road	0		0			9.73			4.1			0.5		48.09	2.88
	North-East Road	1.16		0			4.64			0			9.65		63.33	4.03
4. Existing population density (Persons/ Ha)		**0 - 9**		**10 - 19**			**20 - 29**			**30 - 39**			**40 and above**			
	Churchill Road	18		18			53			11			1	101	262	2.59
	Prospect Road	5		5			37			14			3	64	197	**3.08**
	Main North Road	26		62			72			16			3	179	**445**	2.48
	Hampstead Road	13		25			63			8			0	109	284	2.61
	North-East Road	10		41			53			8			1	113	288	2.55

Selection Criteria	Selected Routes	Suitability Attributes, Parameters, and Classification					Total number of SA1s	Suitability score	Avg. Score
		Least suitable (1)	Less suitable (2)	Moderately suitable (3)	Suitable (4)	Most suitable (5)			
5. Dwellings with no cars (Dwellings/ Ha)		**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 and above**			
	Churchill Road	52	28	19	0	2	101	175	1.73
	Prospect Road	26	23	10	3	2	64	124	**1.94**
	Main North Road	106	55	16	2	0	179	**272**	1.52
	Hampstead Road	83	21	3	1	1	109	143	1.31
	North-East Road	78	26	6	1	2	113	162	1.43
6. Existing bus users (Persons/ Ha)		**0 – 1.25**	**1.25 – 2.5**	**2.5 – 3.75**	**3.75 – 5.00**	**5 and above**			
	Churchill Road	59	33	8	1	0	101	153	1.51
	Prospect Road	12	38	9	4	1	64	136	**2.13**
	Main North Road	113	51	9	5	1	179	**267**	1.49
	Hampstead Road	58	43	8	0	0	109	168	1.54
	North-East Road	36	61	14	2	0	113	208	1.84
7. Existing employed population density (Persons/ Ha)		**0 – 5**	**6 – 11**	**12 – 17**	**18 – 23**	**24 and above**			
	Churchill Road	31	38	27	4	1	101	209	2.07
	Prospect Road	6	21	29	5	3	64	170	**2.66**
	Main North Road	67	58	43	8	3	179	**359**	2.01
	Hampstead Road	20	52	36	1	0	109	236	2.17
	North-East Road	14	56	38	4	1	113	261	2.31
8. The density of school students (Persons/ Ha)		**0 – 3**	**4 – 7**	**8 – 11**	**12 – 15**	**16 and above**			
	Churchill Road	24	43	29	4	1	101	218	2.16
	Prospect Road	5	22	31	5	1	64	167	**2.61**
	Main North Road	43	94	38	3	1	179	**362**	2.02
	Hampstead Road	20	67	22	0	0	109	220	2.02
	North-East Road	24	68	21	0	0	113	223	1.97
9. Availability of vacant land (Hectares)		**Up to 25ha**	**25ha – 50ha**	**50ha – 75ha**	**75ha – 100ha**	**100ha and +**			
	Churchill Road	-	-	-	84.69	-		338.76	18.22
	Prospect Road	13.19	-	-	-	-		13.19	2.22
	Main North Road	-	-	-	-	158.75		**793.75**	**23.69**
	Hampstead Road	-	-	-	81.40	-		325.6	19.53
	North-East Road	-	42.13	-	-	-		84.26	5.37

1

Table 4: Summary of suitability scores of candidate corridors by individually selected criteria

Selected criteria → / **Selected Routes ↓**	Route length	Trip generating existing services	Existing carriageway width	Existing population density	Dwellings with no cars	Existing bus users	Existing employed population density	The density of school students	Availability of vacant land
Churchill Road	74.36	168	57.29	262	175	153	209	218	338.76
Prospect Road	5.94	200	7.35	197	124	136	170	167	13.19
Main North Road	167.5	396	162.5	445	272	267	359	362	793.75
Hampstead Road	66.68	121	48.09	284	143	168	236	220	325.6
North-East Road	47.1	414	63.33	288	162	208	261	223	84.26

4. Multi-Criteria Decision Analysis

As discussed in the previous sections, nine individual criteria have been identified in comparing the suitability of the selected candidate routes. It was assumed that the selection criteria were not of equal weights. A Multi-Criteria Decision Making (MCDM) technique was used as part of this analysis to determine the relevant weights of the selected criteria/variables. Malczewski (1999) has discussed four methods of estimating weights, which are ranking, rating, pairwise comparison, and trade-off analysis.

An Analytical Hierarchy Process (AHP) involves pair-wise comparisons of two attributes relying upon the judgments of experts to determine priority scales (Saaty, 2008). The AHP requires a systematic process that includes the development of a set of pair-wise comparison matrices with values selected from the 'fundamental scale of absolute numbers', which results in the estimation of the respective weights. The process also includes a measure of validation to ensure the consistency of the overall process (Saaty, 2008). Somenahalli et al. (2008) also used the pair-wise comparison method in his analysis, where one criterion was compared against another, independently as a pair, and appropriate weight was given comparing the variables based on a set level of importance ratings or scales. Saaty (2008) suggested a list of scale with a 'nine-level of intensity of importance' in weighing one selection criterion to its relative pair. In his list, the intensity level of 1 represented 'equal importance' of the pair, while 9 represented 'extreme importance' of one variable to the other. The authors used this scale and the described method in a survey of experts and in the analysis of the collected date.

4.1 An expert questionnaire survey

A questionnaire survey was undertaken to collect experts' opinions on the pair-wise relationships of the criteria. Using the analytical Hierarchy Process (AHP), the pair-wise comparison data were then transformed into the final relative weights of the selected criteria. The survey was approved by the University of South Australia's (Adelaide, Australia) Human Research Ethics Committee. The Ethics Protocol reference number is 201849.

For this study, the definition of 'an expert' was kept confined only within the academics, post-doctoral researchers, PhD students and Master degree holders in the Transport Planning / Engineering, and Urban and Reginal Planning disciplines of the University of South Australia, Adelaide, Australia. A total of eleven (11) responses were received including the opinions of the authors. The respondents provided their responses from their independent understanding of a variable and their perceived importance of the variable in the corridor-selection process. Figure 1 demonstrates an example of a response received as part of the survey.

Figure 1: An example survey response (AHP matrix).

Table 2: Pair-wise comparison matrix of selected criteria (the Analytical Hierarchy Process)

	Route Length	Trip Generating existing services	Existing carriageway width	Existing Population Densities	Dwellings with No cars	Existing Bus Users	Existing Employed Population	Density of existing students	Availability of Vacant land
Route Length	1	1	1	1	1	3	1/4	2	4
Trip generating existing services	1	1	1/5	5	1/3	1	1	1	4
Existing carriageway width	1	5	1	8	1	4	¼	2	4
Existing Population Densities	1	1/5	1/8	1	1/3	1/3	2	1	1
Dwellings with No cars	1	3	1	3	1	5	5	7	5
Existing Bus Users	1/3	1	¼	3	1/5	1	4	4	3
Existing Employed Population	4	1	4	½	1/5	1/4	1	3	3
Density of School Students	½	1	½	1	1/7	1/4	1/3	1	1
Availability of Vacant Land	¼	1/4	1/4	1	1/5	1/3	1/3	1	1

4.2 Survey results

It was expected that the relative importance of each of the selected criteria was carefully considered by the respondents and the values were assigned to the pairs based on their perceived relationships with one another. It would be very challenging for the respondents ensuring the values were assigned in a consistent way. Table 5 represents a matrix developed from an average pair-wise comparisons values of the selected nine criteria, while Table 6 demonstrates the estimation of the relevant weights of the criteria, by following the prescribed two-step method of first producing a "*normalised pairwise comparison matrix*" and then by "*computing the average of the matrix elements*" as suggested by Malczewski (1999) and Saaty (2008).

Table 5: Pair-wise comparison matrix (as part of the AHP analysis) of selected criteria (average values from the survey results)

	Route length	**Trip generating existing services**	**Existing carriageway width**	**Existing population density**	**Dwellings with no cars**	**Existing bus users**	**Existing employed population**	**The density of school students**	**Availability of vacant land**
Route length	1.00	1.71	2.29	1.97	3.20	2.48	2.16	2.65	3.36
Trip generating existing services	1.80	1.00	3.35	3.06	3.27	2.62	3.20	3.48	2.91
Existing carriageway width	1.72	1.26	1.00	2.98	2.58	3.05	2.39	2.96	1.95
Existing population density	2.01	1.11	1.81	1.00	2.70	2.81	3.65	2.74	2.98
Dwellings with no cars	0.99	1.14	1.53	0.94	1.00	3.71	3.19	3.39	2.39
Existing bus users	0.95	0.89	1.69	1.22	1.63	1.00	3.68	3.30	2.44
Existing employed population density	2.62	1.03	3.13	1.00	1.93	0.51	1.00	3.09	2.94
The density of school students	1.78	0.47	1.99	1.19	1.55	0.62	0.45	1.00	2.26
Availability of vacant land	1.25	0.47	1.64	0.87	1.60	1.62	1.39	1.98	1.00
Total	**14.1**	**9.06**	**18.42**	**14.22**	**19.47**	**18.44**	**21.13**	**24.59**	**22.24**

Table 6: Estimation of weights of the criteria using AHP analysis (Saaty, 2008, Malczewski, 1999, Somenahalli et al., 2008)

	Route length	Trip generating existing services	Existing carriageway	Existing population	Dwellings with no cars	Existing bus users	Existing employed population	The density of school students	Availability of vacant land	Total Value	Weight of the criterion/variabl
Route length	0.07	0.19	0.12	0.14	0.16	0.13	0.10	0.11	0.15	1.18	**0.13**
Trip generating existing services	0.13	0.11	0.18	0.22	0.17	0.14	0.15	0.14	0.13	1.37	**0.15**
Existing carriageway width	0.12	0.14	0.05	0.21	0.13	0.17	0.11	0.12	0.09	1.14	**0.13**
Existing population density	0.14	0.12	0.10	0.07	0.14	0.15	0.17	0.11	0.13	1.14	**0.13**
Dwellings with no cars	0.07	0.13	0.08	0.07	0.05	0.20	0.15	0.14	0.11	0.99	**0.11**
Existing bus users	0.07	0.10	0.09	0.09	0.08	0.05	0.17	0.13	0.11	0.90	**0.10**
Existing employed population density	0.19	0.11	0.17	0.07	0.10	0.03	0.05	0.13	0.13	0.97	**0.11**
The density of school students	0.13	0.05	0.11	0.08	0.08	0.03	0.02	0.04	0.10	0.65	**0.07**
Availability of vacant land	0.09	0.05	0.09	0.06	0.08	0.09	0.07	0.08	0.04	0.65	**0.07**
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		**1.00**

5. Discussion and Conclusion

The final stage of the analysis is represented in Tables 7 and 8 below, where the final suitability scores were calculated for each of the initial candidate corridors. Scores were calculated separately on the basis of both the total suitability scores and the average scores obtained for each parameter as discussed before. The final suitability scores were calculated by way of summation of the individual suitability scores multiplied by the estimated relative weights of the respective selected criteria.

Table 7: Estimation of final suitability scores (using total score) by selection criteria

	Suitability Scores (Independent variable's total suitability scores × individual variable weights)									
Selected criteria → / **Selected Routes ↓**	Route length	Trip generating existing services	Existing carriageway width	Existing population density	Dwellings with no cars	Existing bus users	Existing employed population density	The density of school students	Availability of vacant land	**Final Suitability Scores**
Churchill Road	9.77	25.56	7.28	33.26	19.34	15.28	22.58	15.65	24.51	173.22
Prospect Road	0.78	30.42	0.93	25.01	13.70	13.58	18.36	11.99	0.95	115.74
Main North Road	22.00	60.24	20.64	56.49	30.05	26.66	38.78	26.00	57.43	**338.30**
Hampstead Road	8.76	18.41	6.11	36.05	15.80	16.78	25.49	15.80	23.56	166.75
North-East Road	6.19	62.98	8.05	36.56	17.90	20.77	28.19	16.01	6.10	202.75

As shown in Table 7, based on the total suitability scores, Main North Road was found to be the most suitable route with a suitability score of 338.30. This level of suitability might also mean that Main North Road would have considerably a higher potential, than other candidate corridors, to be transformed into a bus-based transit corridor. North-East road had the second-highest score of 202.75, while Prospect Road was found to have the least suitability among all candidate corridors with a score of approximately 115.74.

From the consideration of average suitability score assessment, Main North Road was again found to be the most suitable route (with a score of 27.12) among the selected candidate routes. Churchill Road had however scored the second-highest value with a suitability score of 13.90. Prospect Road performed as the least suitable route among all five selected candidate routes. Refer to Table 8 below for the assessment results based on the average suitability scores.

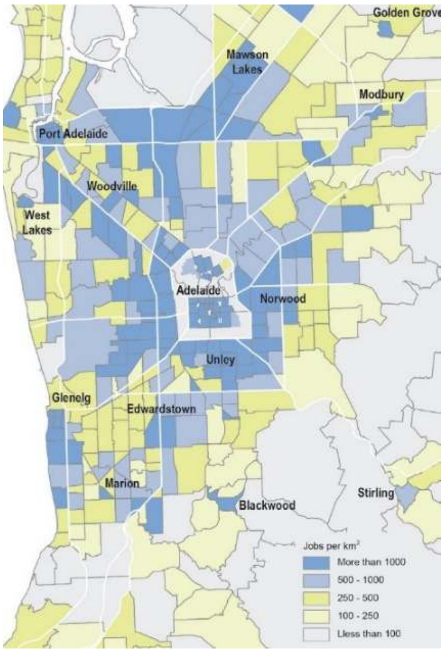
Table 8: Estimation of final suitability scores (using average scores), by selection criteria

Selected criteria → / Selected Routes ↓	**Suitability Scores** (Independent parameter's average suitability scores × individual parameter weights)									**Final Suitability Scores**
	Route length	Trip generating existing services	Existing carriageway width	Existing population density	Dwellings with no cars	Existing bus users	Existing employed population density	The density of school students	Availability of vacant land	
Churchill Road	9.77	1.37	0.39	0.33	0.19	0.15	0.22	0.16	1.32	13.90
Prospect Road	0.78	5.12	0.16	0.39	0.21	0.21	0.29	0.19	0.16	7.51
Main North Road	22.00	1.80	0.62	0.31	0.17	0.15	0.22	0.15	1.71	**27.12**
Hampstead Road	8.76	1.10	0.37	0.33	0.14	0.15	0.23	0.15	1.41	12.65
North-East Road	6.19	4.01	0.51	0.32	0.16	0.18	0.25	0.14	0.39	12.16

As discussed above, the concept of transit-oriented developments (BTODs) along new bus transit corridors was considered as an alternative viable option to rail services for the outer suburban areas of metropolitan Adelaide, where bus rapid transit (BRT) style services can provide for improved accessibility and reliability on the bus services. The selection process of a suitable corridor for a BRT service was crucial as the function of a corridor was identified to be two-fold. Firstly, the existing capacity of a route to be able to accommodate all physical infrastructure needed in a cost-effective way and, secondly, the route's accessibility to the required demographic and land use characteristics for the development of future BTODs. This study successfully identified Main North Road (among five candidate corridors) as the most suitable route from both perspectives.

This paper acknowledges that several other variables could be considered as part of the corridor selection process. The existing number of bus services and their corresponding number of bus users could be an important indicator/ variable of this selection study. This was not considered in the study as the initial candidate routes were selected based on the arterial nature of the major roads, rather than following the existing bus routes. Another important variable is the 'density of employment', which could not be included as a variable as the necessary dataset at the required geographic area level (i.e. Statistical Area - SA1) was not available. However, the cumulative employment data used in the draft 30 Year Plan for Greater Adelaide-2016 (refer to Figure 2) showed relatively a higher employment density along Main North Road corridor. Refer to Figure 3 for the 'density of employment' map presented in the report.

Figure 2: Density of employment in Metropolitan Adelaide.
(Source: The Draft 30 Year Plan for Greater Adelaide- Update 2016)



This study demonstrated a method of quantifying qualitative attributes of nine (9) selected criteria into one comparable unit. It also demonstrated the use of the Analytical Hierarchy Process in determining the relative weights of the selected criteria, which were considered to have non-equal importance in the selection of the final corridor. The results were obtained by analysing pair-wise variable comparison data collected by a survey of experts in the Transport Planning/ Engineering field. Although the respondents were made aware of the scope of the study and were given clear instructions on the definition and parameters of the variable, their responses were independent and diverse. As the average values of the responses were considered in the analysis, it was also difficult to ascertain the consistency of the overall responses.

Overall, this study has followed a clear methodology with an introduction of a new technique in the selection of a transit corridor (for BTODs). This study is however considered to provide a guideline/ methodology for future studies of similar nature, where several routes and a range of attributes may need consideration in the selection of a transit corridor.

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