Evaluating the LUPTAI Accessibility Model: A Case Study of a Proposed Green Bridge in Brisbane

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Abstract

The Land Use and Public Transport Accessibility Index (LUPTAI) method was originally developed in 2006 to help state and local transport agencies evaluate whether people were able to access important destinations by public transport and walking. Queensland's Department of Transport and Main Roads invested in the development of an ArcGIS add-on to facilitate the creation of LUPTAI models, leading to the evolution and expansion of the method in the past decade. This paper discusses the expanded LUPTAI and compares it with other in-practice accessibility models used across Australia, New Zealand, and the world. LUPTAI compares favourably with other accessibility models used by state and local governments. Then, the paper presents an application of LUPTAI to a proposed active transport bridge near the University of Queensland's St. Lucia campus (UQ). Leveraging LUPTAI, this analysis investigates the proposed bridge's impact on access by walking, cycling, and public transport to UQ and on general accessibility in Brisbane. The results provide evidence that the proposed bridge would improve walking and cycling access to UQ. However, the general accessibility analysis suggests that while walking accessibility would improve in the areas adjacent to the bridge, cycling and public transport accessibility would not be greatly impacted by the addition of the bridge. Overall, the results show the significant utility of the LUPTAI model for analysis of transport accessibility improvements.

1. Introduction

LUPTAI was initially developed to assist the Department of Transport and Main Roads (TMR) and local governments assess peoples' ability to reach important destinations by public transport and walking (Pitot et al, 2006). Since LUPTAI's initial development, TMR expanded the index to include cycling and car accessibility options as well. TMR invested in the creation of a bespoke ArcGIS add-on that allows modellers to conduct their own LUPTAI accessibility analyses and explore the accessibility implications of different projects and scenarios (Peter Davidson Consulting, 2008). The automation of LUPTAI in this software allowed for the implementation of more advanced calculation methods than discussed in the initial paper.

This paper will compare LUPTAI to other accessibility tools used by local and state governments across Australasia and the world. Next, the paper will explain the LUPTAI methodology, placing a particular emphasis on the portions of the method that have changed since the original paper. Then the LUPTAI tool is applied to a case study in Brisbane, Australia to showcase LUPTAI's capabilities. The Transport Strategies portion of the UQ St. Lucia Campus Master Plan (MRCagney Pty. Ltd., 2017) proposes building a green bridge near the St. Lucia campus to enable walkers and cyclists to access its campus more easily. Using LUPTAI, this analysis explores the impact of the proposed bridge on accessibility by walking,

cycling, and public transport to the University of Queensland, in addition to investigating the impact of the bridge on general accessibility. Additional reflections on the value of the LUPTAI model are also included in the summary.

2. Literature Review

Over the past several decades, transport planners and researchers have generated a wealth of research on the topic of transport accessibility. This review focuses on transport accessibility models used in practice and the tools created to implement these models.

2.1. Accessibility Models in Australia and New Zealand

An Austroads report (Espada, Luck, & ARRB Group, 2011) titled *The Application of Accessibility Measures* (AAM) appears to be the most comprehensive review of in-practice accessibility models conducted in Australia. The report aims to establish a standard accessibility metric and to benchmark the metric against existing methods. The AAM standard metric, referred to as AAM, is estimated at either the strategic level with traffic zones or at the neighbourhood level with grid cells of resolution 100 meters. AAM inputs include the number of opportunities in a zone (jobs, schools, retail, and recreation) and an impedance matrix of generalized travel cost pulled from transportation models. In the report AAM performance is compared to three other accessibility models: LUPTAI, the Koenig accessibility metric (Koenig, 1974), and the New Zealand Transport Agency (NZTA) accessibility measure. AAM and LUPTAI estimate similar levels of accessibility with differences attributed to different methods of aggregating data.

Abley Transportation Consultants and Derek Halden Consultancy investigated a similar subject in a report for NZTA, which reviewed accessibility tools and methodologies from New Zealand and Europe (Abley & Halden, 2013). The NZTA report takes care to outline the accessibility indicators most commonly used in practice and is another excellent resource for agencies wishing to build or to benchmark an accessibility model. Additionally, this report develops the previously mentioned NZTA Accessibility Measure (NAM) and tests it in a Christchurch pilot project. This ArcGIS-based model considers the accessibility of a site to important destinations such as jobs, hospitals, schools, and shops over time. The model uses the centroids of mesh blocks or parcels as origins. A negative exponential function converts shortest path travel times between origins and destinations to raw accessibility indices. The model builds the final accessibility score by combining the raw accessibility indices to account for multiple opportunities and weights the combined scores by mode, activity, and age of the population.

Several Australian organizations responsible for public transport planning and policy rely on Public Transport Accessibility Levels (PTAL). PTAL was originally developed in the United Kingdom by the London Borough of Hammersmith and Fulham (Transport for London, 2010) but has since been adopted by many transport agencies overseas. PTAL estimates the ease of access to public transport. This measure considers walking time from an origin to a public transport (PT) access point, the reliability of services, frequency of service, and average waiting time for a service. PTAL is relatively simple to implement and has limited data requirements. In Australia, Transport for NSW created an interactive, web-based ArcGIS mapping tool utilizing PTAL (Transport for NSW, 2015). The tool leverages Australian Bureau of Statistics (ABS) data at the SA1 level and visualizes PTAL for different population densities and regions. The Green Building Council of Australia created the Excel-based, Access by Public Transport Calculator, a publically available tool which measures the number of residents within a 45 minute "effective travel time" of a destination (Green Building Council of Australia, 2015).

Some local governments have chosen to maintain their own accessibility models. Sutherland Shire Council, NSW, Australia, developed an Accessibility Constraints Map (ACM) (Koernicke, 2007). ACM aims to understand which places have limited public transport and walking access

to key activities. The Council uses the tool for land use planning and transport infrastructure enhancements. ACM assigns accessibility scores to land parcels based on walking path availability, frequency of public transport services, and the proximity to public transport and activities. Sutherland Shire Council determined score weightings using data from a survey of residents. The ACM tool is implemented as GIS map layers within the Council's larger GIS.

The Modular Urban Land Use and Transport Tool (MULUTT) is an example of an accessibility model developed for a specific project. City of Gold Coast, QLD, Australia, applied the GIS-based model during the location selection process for a new Australian Football League stadium within the city. In addition to transport assessment, MULUTT analyses housing locations with respect to oil vulnerability and the balance between housing and jobs (Curtis, Scheurer, & Burke, 2013). In the Gold Coast case study, the model sets two thresholds for 'door-to-door' access: 45 and 75 minutes from home to the possible site locations. The tool locates places on the network that are accessible by scheduled public transport services within these thresholds and identifies the number of residents living in that area.

Another accessibility model that has been used several times in the Australian context is the Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS). While the software is not freely available to the public, the creators of the commercial software have consulted on several transportation planning studies in Australian and international cities. SNAMUTS runs on a GIS-based platform, combining measures representing different aspects of transport network 'centrality and connectivity' at the urban scale (Curtis & Scheurer, 2010). SNAMUTS links the frequency of public transport service to surrounding land use opportunities. The model calculates eight accessibility metrics for any pair of activity centres with the provided frequency of public transport in the inter-peak time. The final composite accessibility index is a weighted sum of accessibility measurements. SNAMUTS was used to assess the accessibility impacts of a new rail line in Perth, WA (Curtis, 2011), included in the development of a strategic plan for the Public Transport Authority of Western Australia (Curtis, Scheurer, & Burke, 2013), and was applied to the Melbourne public transport network (Curtis & Scheurer, 2010).

2.2. International Accessibility Tools and Models

Measuring transportation accessibility is a topic of international interest. This section will discuss a small number of well-known or particularly relevant in-practice international accessibility models. Accession, a well-known accessibility modelling software, was created by Department for Transport in the UK to standardize the use of accessibility indicators across different agencies and stakeholders. Accession is intended to be easy to use and leverage existing data sources. Bus operators, national surveys, local governments, and the census provide the necessary input data for Accession (Brown & Wood, 2004). A New Zealand report describes a trial version of Accession as considering the accessibility of walking, public transport, cycling and private car (Abley & Halden, 2013). ACCALC, a Scotland-based accessibility model, is currently used to update the annual national core accessibility indicators of the mainland UK. Most of the model input data comes from open sources; however, some additional data on commercial land uses was purchased separately for this application. Developers expressed the need to implement user data standards to further improve the tool (Halden, 2012). In addition to the previously mentioned PTAL measure, Transport for London also conducts Time mapping (TIM) and calculates Access to Opportunities and Services (ATOS). TIM calculates the time between zones, accounting for various barriers such as lifts, steps, and ramps at stations. ATOS is calculated from travel times to the ten nearest 'desirable destinations', a set that includes employment centres, schools, hospitals, shopping centres, and open spaces (Transport for London, 2015). Researchers from the United States and the Netherlands developed a multimodal accessibility model, referred to in this paper as the Amsterdam Accessibility Methodology that uses Open Street Map (OSM) and Google's General Transit Feed Specification (GTFS) data (Open Street Map, 2017; Google Developers, 2017). This model is geared towards sketch planning and has been applied to alternative

development scenarios in metropolitan Amsterdam, the Netherlands (Conway, Byrd, & van der Linden, 2017). The Amsterdam Accessibility Methodology is of particular relevance this research due to its use of a Monte Carlo simulation to randomly generate public transport routes.

Table 1 summarizes the models discussed in the literature review. The table breaks down each of the models into five common components of accessibility. While the different models may take varying approaches to measuring these components, the table simply records which accessibility components the model attempts to incorporate. *Access to public transport* indicates the ability of a tool to take into account walking access to a public transport stop or station. *Frequency of service* indicates whether the model considered the temporal aspects of accessibility. This may include actual frequency of service or the use of schedule data. *Reliability* indicates whether the model considers the on-time performance of a particular journey. *Connectivity* indicates that a model considers all parts of a journey, from origin to destination, on a network. *Multimodal* indicates whether more than one mode of transport is available for estimation in a current instrument. LUPTAI captures four of the five accessibility components.

Table 1: Comparison of Accessibility Instruments

Name	Access to public transport	Frequency of service	Reliability	Connectivity	Multimodal
LUPTAI	•	•		•	•
AAM	•	•		•	•
ACCALC	•	•	•	•	•
Accession	•	•		•	•
ACM	•	•			
ATOS	•			•	•
Amsterdam Accessibility methodology	•	•		•	•
MULUTT	•	•		•	•
NZTA Accessibility Measure	•	•	•	•	•
PTALs NSW	•	•	•		
SNAMUTS	•	•		•	•
TIM				•	•

3. Methodology

LUPTAI is among the most comprehensive accessibility models in active use by a transport agency. As its name suggests, LUPTAI focuses on accessibility by public transport and other modes to specific land uses, or 'activities'. The methodology was developed for TMR in 2006 but has evolved substantially in the intervening decade. LUPTAI estimates door to door travel times, simulating travellers' destination choices and arrival times using Monte Carlo simulations. Results for different modes and time periods are provided separately. Results for different activity types can also be provided separately or be combined into composite values using a set of weights. The LUPTAI software, a bespoke add-on to ArcGIS 10.1 (ESRI, 2011), allows users to customize the time window for which LUPTAI is calculated. The use of the Monte Carlo method to simulate traveller choice in an accessibility model appears to be unique among accessibility models. While the Amsterdam Accessibility Method uses Monte Carlo simulations to generate schedules for routes with proposed service changes, it does not use

the method to simulate traveller behaviour. One of the benefits to using this method is it allows the modeller to retain trip travel time as the measure of accessibility without assuming that all travellers will take the shortest path to the nearest destination.

Many aspects of the LUPTAI methodology are adaptable to the needs of a particular model within the LUPTAI software. The following sections will discuss core methodologies and primary data sources, focusing on those necessary for the application presented in Section 4.

3.1. Estimating Accessibility with the Monte Carlo Method

Within LUPTAI, the final accessibility values may be interpreted as the average estimated travel times to an activity from a particular location. The LUPTAI method assumes that a traveller's choice of destination will follow a binomial distribution, meaning every destination associated with a particular activity is either suitable or unsuitable to a traveller's needs. The probability that a particular destination will be unsuitable for a traveller's needs is referred to as the exclusion probability (Peter Davidson Consulting, 2008, pp 14-16; 23-24). For some activities, such as shopping at convenience stores, LUPTAI assumes every destination is suitable to a traveller's needs and assigns the activities an exclusion probability of zero. However, for other activities, travellers may be more selective about their destination. Dentists and general practitioners have the highest exclusion probabilities, outside of employment. The default values for exclusion probabilities were derived from a calibration process which sought to match the average travel times by purpose found by LUPTAI to those found by the 2004 South East Queensland (SEQ) Household Travel Survey (HTS).

Once the exclusion probabilities are defined, LUPTAI conducts a Monte Carlo simulation that determines which of the possible trip destinations meet the traveller's needs. Each destination from a particular set (e.g., employment, green space, convenience store, health centre) is randomly selected as an eligible destination, based on the exclusion probability. For example, with a 1 in 4 exclusion probability for a grocery store, only one-quarter of all grocery stores are randomly selected as eligible destinations. Access to jobs is treated differently. All jobs within an SA1, an Australian census area, are located at the same point which is assigned an attribute representing the number of jobs. The Monte Carlo simulation will apply the exclusion probability to the number of jobs. The simulation randomly selects arrival times, assuming they follow a uniform distribution over the user-specified period of analysis. Then, a shortest path algorithm determines the travel time to the nearest of the eligible destinations. This simulation process repeats 50 times, each time selecting a different arrival time and set of eligible destinations. The average travel time over all 50 simulations is selected is the final measure of accessibility. TMR modellers selected 50 simulations as the default based on their experience using the model but users may adjust the number of simulations if they wish.

3.2. Inputs and Datasets

LUPTAI requires two primary types of input data: network data and activity data. While the models developed by Queensland rely on mixture of publically available and proprietary data, the model presented in the application section uses only publically available data.

3.2.1. Network and Activity Data

The example model, presented in section 4, requires a public transport and active transport network. The LUPTAI accessibility model requires a schedule-based PT network. While the technical document mentions several compatible sources of network data, the current source of the SEQ model's PT network data is the SEQ GTFS (Lowes, pp 37-39). GTFS files are standardized, widespread, and require quarterly updates by the organization responsible for

their maintenance. This makes GTFS files an excellent data source of schedule-based PT network data.

The activity location data available within the LUPTAI software is drawn from TMR's internal data.

3.2.2. Weights and Exclusion Probabilities

As mentioned in section 3.1, exclusion probabilities are used within the Monte Carlo method to simulate the likelihood of an activity node being unsuitable for a particular user. Activity weights are used to combine activity-specific accessibility scores into a single composite accessibility score. Weights are between 0 and 1 with larger weights indicating the activity is of relatively greater importance. The weights were selected by TMR. Table 2 below shows all the activities that will be considered in the application in Section 4, along with their associated weights and exclusion probabilities.

Table 2: Activity Parameters: Exclusion Probabilities and Weights
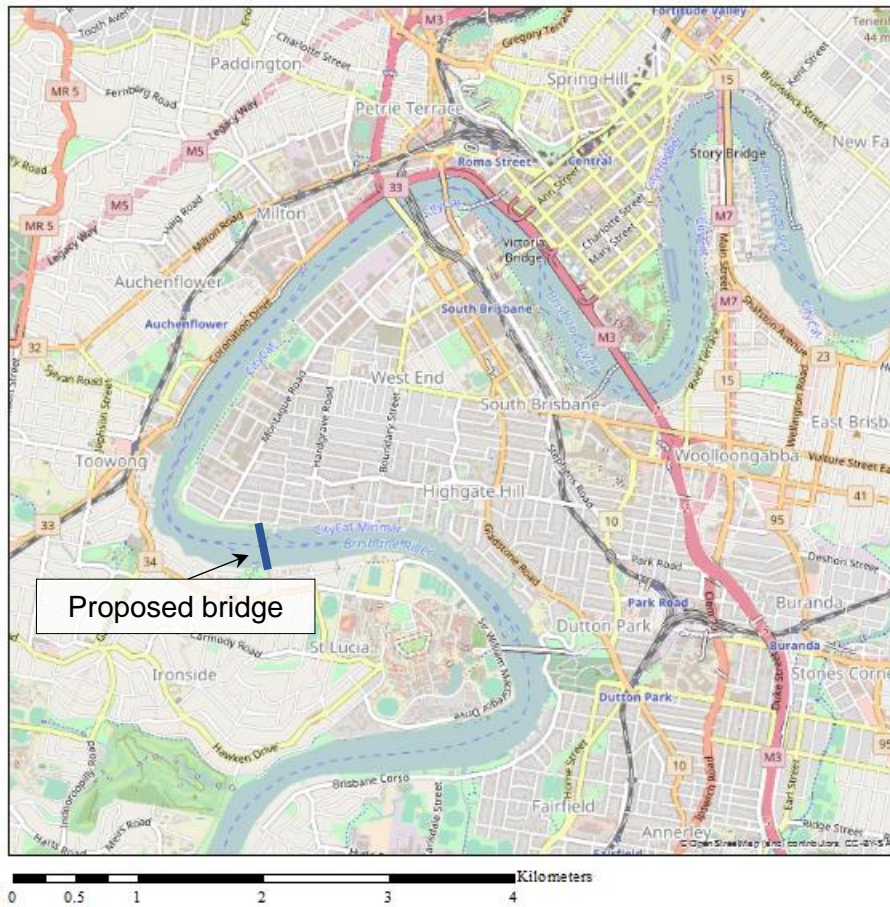
Activity	Exclusion Probability	Weights
Hospital	0.4	0.5
Library	0	0.5
Major Shops	0.1	0.7
Misc Shops	0.2	0.7
Primary School	0.2	0.7
Secondary School	0.3	0.7
Supermarket	0.1	1
Tertiary	0.5	0.7
Welfare	0	0.5
Employment	0.999	1

4. Application

In this section, LUPTAI is used to analyse the accessibility impacts of one of the proposed infrastructure changes in UQ's transport plan, a green bridge connecting Guyatt Park in the suburb of St Lucia and Orleigh Park in the suburb of the West End. The proposed bridge, shown in Figure 1 below, would offer pedestrians and cyclists a new river crossing near UQ. A link representing the bridge and its proposed alignment was added to the existing network layer for Brisbane. We assumed the bridge would encourage separation of travellers by directions but that pedestrians and cyclists travelling in the same direction would mix. This analysis will first consider whether the proposed green bridge improves walking, cycling, and public transport access to UQ. Then we consider whether the bridge improves general accessibility in Brisbane City by generating combined scores for all destination types for walking, cycling, and public transport.

Figure 1. Map of study and proposed alignment of the West End-Guyatt Park Green Bridge.

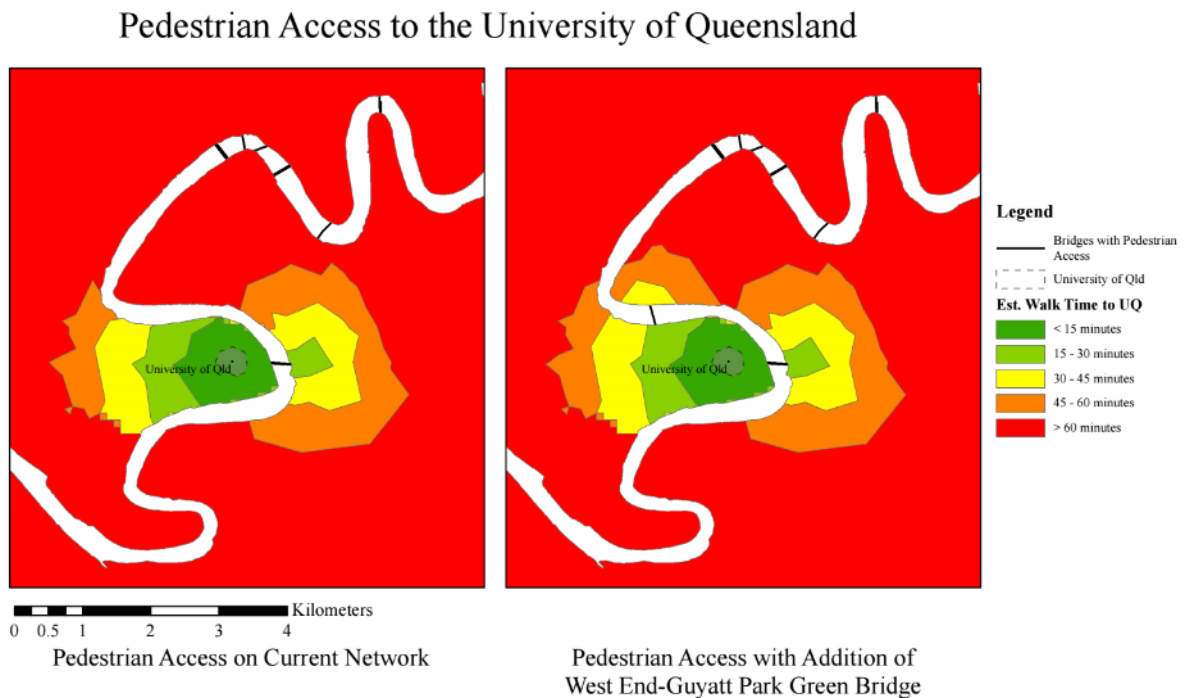## 4.1. Access to the University of Queensland

The first set of analyses looks exclusively at the access to UQ. UQ is modelled as a set of activity points with an exclusion probability of 0.5 rather than as a single destination or activity. Walking from a building on the edge of campus to the campus core can take over 5 minutes, therefore it is important to consider different on-campus destinations. As expected, the addition of a walking and cycling bridge between Guyatt Park and the West End greatly improved the West End's walking access to UQ. Figure 2 shows an example of the raw output of the LUPTAI software tool for walking to UQ with the bridge. Note that the software measures accessibility from specific locations in the transport network; this gives the point-specific measures seen in Figure 2.

Figure 2. LUPTAI accessibility analysis output

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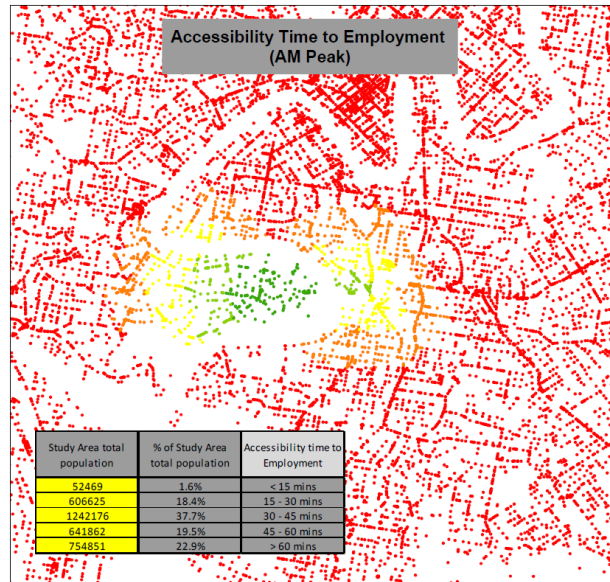
Using the inverse distance weighting method, available as a function in ArcGIS, the LUPTAI software output can be transformed into contour lines estimating travel times to UQ. Figure 3 shows the difference in estimated walking times to UQ with and without the proposed bridge.

Figure 3. Contour Map of Pedestrian access to UQ with and without the proposed West End – Guyatt Park Green Bridge.

Pedestrian Access to the University of Queensland

Pedestrian Access on Current Network

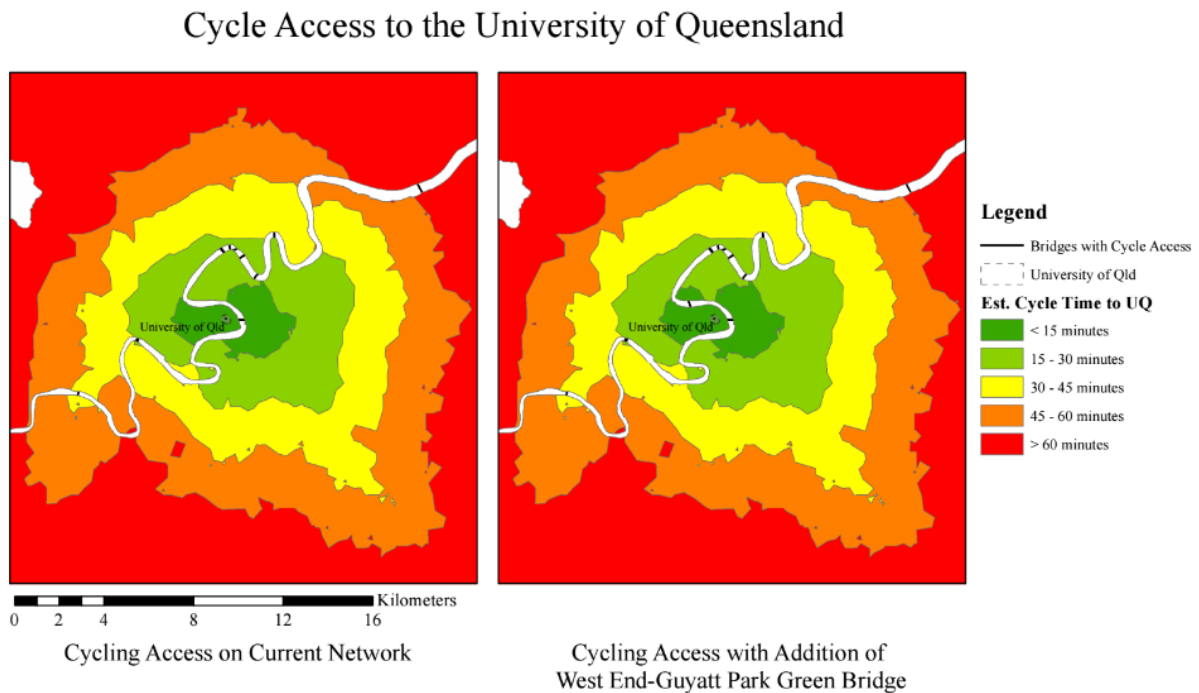Pedestrian Access with Addition of West End-Guyatt Park Green Bridge

The bridge makes a noticeable difference in the travel times for people living in the West End peninsula. However, it is worth noting that the estimated walking times found through the LUPTAI analysis were more conservative than the estimated walking times presented in the UQ Transport Strategies (MRCagney Pty. Ltd., 2017). The output of this analysis suggests that even with the new bridge, people will not be able to walk from anywhere in West End to UQ in under 30 minutes.

A similar analysis was conducted for cycling. Figure 4 shows the difference in estimated cycling times to UQ with and without the proposed bridge.

Figure 4. Contour maps of cycling access to the UQ with and without the proposed West End – Guyatt Park Green Bridge.

Cycle Access to the University of Queensland

Cycling Access on Current Network

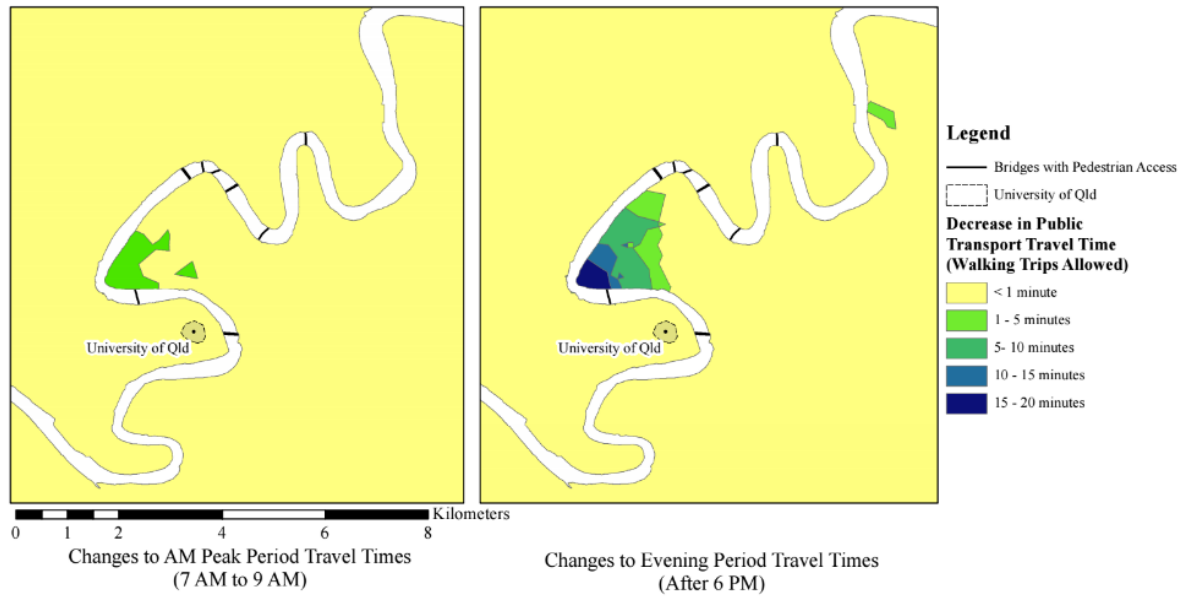Cycling Access with Addition of West End-Guyatt Park Green Bridge

Similar to the pedestrian analysis, the cycling times improved substantially in the West End peninsula. While the impact on the West End was not surprising, the lack of impact elsewhere in the network was a bit unexpected. This may be due to the existence of alternative paths which offer cyclists benefits such as fully separated lanes. The LUPTAI model adjusts cycling speeds to account for available cycling infrastructure. The fully separate cycleway on the north side of the river would assume cyclists traveling at much faster speeds than the routes cutting through the West End's local roads and mixed-use paths.

The public transportation analysis was conducted for two time periods: the AM peak and the later evening (post PM peak). In this analysis, travellers may walk to and from public transport services. The model also allows walk-only trips in cases where the estimated walk time is shorter than the estimated public transport travel time. While it is possible to create public transport contours, the contours are difficult to interpret; therefore, this analysis will map the differences in estimated travel time. The LUPTAI software offers a comparative analysis tool, which calculates the differences between estimated travel times under different scenarios. Figure 5 below shows the changes in travel times with and without the bridge during the AM Peak and in the later evening.

Figure 5: Changes in accessibility to UQ by public transport with and without the proposed West End – Guyatt Park Green Bridge.
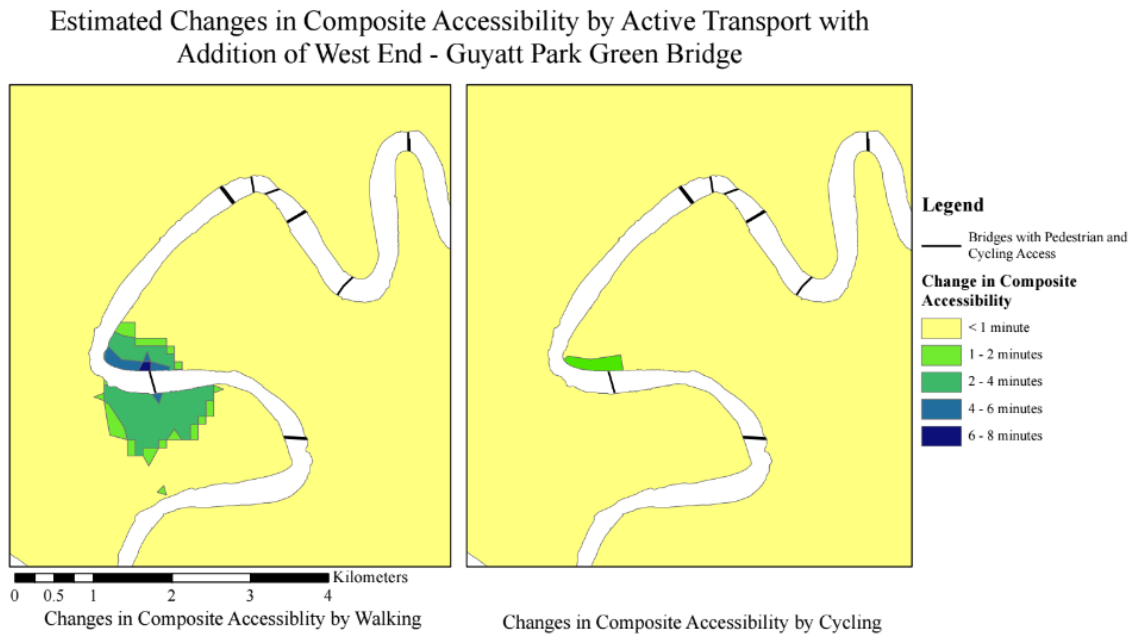

Changes in public transport accessibility to the West End are relatively small during the peak period, but travellers will see a large increase in accessibility in the evening hours. There are relatively few public transport services connecting UQ and the West End and even fewer which offer service in the later evening. By building the Guyatt Park – West End Green Bridge, people travelling to UQ can take advantage of the buses with evening service operating in the West End and walking the final portion of their trip. These improvements to the public transport accessibility assume travellers are able and willing to walk at least 30 minutes.

4.2. Changes to Composite Accessibility

In addition to understanding the impacts of the proposed bridge on people travelling to UQ, we are also interested in the effects of the bridge on general accessibility. The composite accessibility analysis considers all activity types shown in Table 2. LUPTAI calculates a composite accessibility value by combining the estimated travel time for each activity using the weights in Table 1. The figure below shows changes in walking and cycling composite accessibility.

Figure 6: Change in composite access by walking and cycling with and without the proposed West End – Guyatt Park Green Bridge.

Estimated Changes in Composite Accessibility by Active Transport with Addition of West End - Guyatt Park Green Bridge

The changes to composite accessibility are smaller in both size and reach than the changes in access to UQ. All of the changes to composite accessibility using public transport during the time periods of interest are less than 2 minutes. Locations with composite public transport accessibility increases between 1-2 minutes are immediately adjacent to the bridge and are less than 300 m wide. Changes to composite accessibility values are much smaller than the changes for the UQ-specific accessibility values due to the existing distribution of activities. While it is difficult to cross this particular stretch of the river as a pedestrian or cyclist, it may not be necessary for people to make this crossing when similar activities are located nearer their origin. From this perspective, the improvements in overall accessibility from this green bridge appear to be highly localised.

5. Conclusion

LUPTAI's methodological approach compares favourably with the best in-practice accessibility models from around Australasia and the world and the LUPTAI software provides the tools for users to implement the methods on their own. In this paper, LUPTAI enabled the exploration of changes to accessibility that may result from a new green bridge proposed in the UQ Transport Master Plan. The proposed bridge would connect the West End peninsula to St. Lucia, which is currently unreachable from the West End by foot in under 60 minutes or by bicycle in under 30 minutes. The UQ Transportation Plan suggests that the bridge will greatly improve the ability of people to use active transportation to commute to work and will provide greater general accessibility between the West End, St. Lucia, and other communities.

The LUPTAI accessibility analysis provided clear evidence that the bridge would improve peoples' ability to reach UQ from the West End by foot and bicycle, as expected. However, changes in accessibility by public transport are more limited. During the AM peak, the addition of the bridge improves people's door to door public transport travel times by less than 5 minutes for some people in the West End. In the evening (after 6 PM), the analysis shows greater improvements in accessibility in the West End. In both cases, the changes in accessibility are likely the result of trips that are shorter if a traveller chooses to take public

transport within the West End and then walks the final leg of the trip to the UQ campus (or vice-versa). Not all public transport users will be able or willing to walk the 25-30 minutes necessary to reach campus from the proposed bridge site in Guyatt Park. We caution from interpreting the improvements in the public transport accessibility as meaning that people will be better able to reach UQ using public transport, as most improvements require users to make a lengthy walk.

An analysis of the composite accessibility with and without the proposed bridge provided limited evidence that this green bridge would improve general accessibility. Changes to composite walking accessibility are small in scale, and limited to areas directly adjacent to the bridge. Changes in composite access by cycling and public transport in the time periods of interest are small, suggesting that travellers would experience less than 2 minutes improvement in their average trip travel times to various activities. The lack of any significant changes is due to the distribution of activities across the network. In most cases, the addition of the bridge does not offer people significantly nearer activities than are available under the existing system. While the bridge may be valuable in improving access for those commuting to and from UQ, this analysis does not suggest it is useful to improving general accessibility.

While this analysis suggests the bridge does not provide broad accessibility benefits outside of those commuting to UQ from the West End, there are other goals that the proposed bridge might achieve. For example, a bridge between Guyatt Park and West End would create a more connected cycling and walking network that may be particularly valuable to recreational cyclists, joggers, and walkers. In the future, it would be useful to investigate other alternatives for improving the connection between West End and UQ, such as running a high frequency ferry service that operates later into the evening.

TMR's LUPTAI software greatly improves the capacity of planners and researchers to create accessibility models in a reasonable amount of time, enabling comparative analyses like the one shown in this paper. Those outside of transport planning can easily understand LUPTAI's outputs, making LUPTAI a powerful tool for explaining the impact of transport projects to both the public and policymakers.

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