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A GIS-based land use and public transport accessibility indexing model

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Abstract

Accessibility indexing is important in evaluating existing land use patterns and transportation services, predicting travel demands and allocating transportation investments. A GIS-based land use and public transport accessibility indexing model has been developed for measuring and mapping levels of accessibility to basic community services by walking and/or public transport, within local government areas. The model aims to assist the planning and decision making process to deliver integrated land use and transportation outcomes. It is an origin-based accessibility model that determines levels of accessibility by utilising GIS analysis techniques to measures accessibility based on both actual walking distances and public transport travel time. The model has been applied to two pilot studies in the Gold Coast City to assess its practicality and effectiveness. This paper outlines the methodology of the model and the findings related to these pilot studies. The paper also demonstrates benefits and application of the model to other urbanised local government areas.

Introduction

Accessibility is one of the key issues of transport and land use planning. It reflects the ease of reaching needed/desired activities and thus reflects characteristics of both the land use system and the transportation system (Handy and Clifton, 2001; Wu and Hine, 2003). It is crucial to allocate necessary land use destinations (LUDs) and to provide public transport (PT) networks within close proximity that would take people to these LUDs (e.g. goods, services, employment, social contacts) within a reasonable travel time (Hine and Mitchell, 2003).

Transport and land use planning has a significant role in promoting accessibility, and at the same time accessibility is becoming increasingly important in making sound and sustainable land use and transport decisions (ODPM, 2003; Bertolini et al., 2005). Therefore it is important to develop models that are able to measure accessibility to PT networks and LUDs (Handy and Niemeier, 1997). Additionally, within these models accessibility standards are required in order to establish better land use and transport planning strategies and policies (Tyler, 1997). Although there have been several accessibility models previously developed, only a few considered access to PT and basic community services by using walking and PT modes, with a limited number implemented successfully in complex urban environments.

The primary objective of this research is to develop a comprehensive accessibility indexing model – *The Land Use and Public Transport Accessibility Indexing Model (LUPTAI)* – which is accurate, straightforward, transparent enough to be understood by the general public,

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applicable to the Queensland context, and able to be replicated by other states. The secondary objective is to test its compatibility in a complex urban environment in South East Queensland (SEQ).

This paper is organised in four sections. First, we review theoretical discourses on accessibility, and discuss strength and weaknesses of existing accessibility indexing models. Secondly, we present the conceptual and methodological approach of LUPTAI. Thirdly, we focus and discuss possible implementation areas of LUPTAI in different planning applications and scales, and we present the findings of the two pilot studies. And Lastly, we outline policy implications of and further developments in LUPTAI.

Accessibility models

Accessibility essentially describes an individual's ability to reach desired goods, services, activities and destinations – collectively, 'opportunities' (Litman, 2003). Although a seemingly simple concept, accessibility has proven elusive to define and measure. Geurs and van Wee (2004) argue that despite the important role that accessibility plays in policy making, it is often misunderstood, poorly defined and a poorly measured construct. This is a reflection of the underlying complexity of accessibility as a multi-faceted concept.

An assessment of transport from an accessibility approach could help in addressing issues of equity and transport disadvantage. This is a desirable outcome, as a socially just transport system provides a fair distribution of transport services and equal access to LUDs (Department of Transport, 2001).

Accessibility is strongly affected by the design of infrastructure such as PT routes and stops, road network, and the availability of various LUDs in a close proximity. It is also influenced by problems such as the legibility of a timetable and the perception of safety (Tyler, 1999). According to Bertolini and le Clercq (2003) accessibility can be directly related to both the qualities of the transport system (e.g. travel speed), and the qualities of the land use system (e.g. densities and mixes). At the same time it can also be directly related to economic goals (access to workers, customers, suppliers), social goals (access to employment, goods, services, social contacts), and environmental goals (resource-efficiency of activity/mobility patterns).

Cervero (1997) considers the paradigm shift from 'automobility planning' to 'accessibility planning' as an appropriate means of increasing accessibility and decreasing the negative impacts of transportation on the environment. Wixey et al. (2005) identifies several aspects in which accessibility has been used for planning purposes, which include: (a) access to opportunities; (b) distribution of transport impacts; (c) travel options; (d) consistency of transport; (e) linkages with public policies; (f) impacts of new developments; and (g) community and business travel planning.

In recent years, Australian state governments have started to realise the importance of accessibility. For example, one of the key policy strategies of the Melbourne 2030 is to plan urban development around high levels of accessibility to jobs and community services more accessible (Victorian Government, 2002). The primary goal of the Perth Metropolitan Transportation Strategy 1995-2029 is to improve and enhance accessibility throughout the whole metropolitan area (Ministry for Planning, 1995). Sydney's Metropolitan Strategy views accessibility as an important policy for self-sustaining (Department of Infrastructure Planning, 2004). The Planning Strategy for Metropolitan Adelaide underlines the importance of enhancing accessibility and ensuring a fair distribution of resources throughout the urban area (South Australian Government, 2005). Similar to all above in SEQ Regional Plan 2005-2026 accessibility is also identified as one of the desirable regional outcomes (Queensland Government, 2005).

Given that a reasonable level of fair and equitable access for all is a desired outcome for transport systems, an accessibility indexing model which monitors of a transport system's performance is greatly beneficiary for land use and transport planning (DHC&UW, 2004). The importance of developing a composite transport and pedestrian oriented accessibility index is evident in land use and transportation literature (e.g. Hardcastle and Cleeve, 1995; Hillman and Pool, 1997; Ewing and Cervero, 2001; Handy and Clifton, 2001). However because of the complexity of developing accessibility indices, both within Australia and overseas, there has been limited research conducted on measuring accessibility and developing indices for planning purposes.

One of the successful accessibility model developed, is the 'Accession' software by MVA and Citilabs. Accession is a GIS-based model and combines data on the local transport network and location of services with information on disadvantaged areas and demographic groups to identify particular accessibility problems. Accession used the following layers in measuring accessibility: PT data, road networks, LUDs, and demographic data. It also covers a range of modes, including PT, car, flexibly routed services, walking and cycling (AccessionGIS, 2006). The only downfall of this accessibility model is that it is not an open source model, therefore it can only be run via specific software (Accession and Geomedia).

The second example is the accessibility model modified and developed by the Transport Studies Group. In their recent research they explored how a geographic accessibility index can be designed to quantify service accessibility within urban areas with a special focus on socially disadvantaged groups. They proposed enhancements on the two existing strategic accessibility measuring tools, 'Calculator for Public Transport Accessibility in London' (CAPITAL) and 'Public Transport Accessibility Mapper for West Yorkshire' (PTAM). This research also developed an accessibility planning tool to be used by local councils, which is called 'Weighted Access for Local Catchments' (WALC). These models used the combination of the following layers: local walking network, PT network, labour markets, financial services, education and training, healthcare, food shops and social, cultural and religious activity centres as the main LUDs (Wixey et al., 2005).

The third example is the GIS-based accessibility model developed by Liu and Zhu (2004). This model provides a general framework for integrated use of GIS, travel impedance measurement tools and accessibility measures to support the accessibility analysis process. It includes formulating the concept of accessibility, selecting or developing accessibility measures, specifying the accessibility measures, deriving the accessibility values using the selected or developed accessibility measures, and presenting and interpreting the accessibility values. This model measures accessibility by PT to shopping centres, healthcare services, public schools, banks, post-offices, parks and community centres. This model also develops a composite index combining these different measures (Zhu et al., 2005). However this model does not consider walking modes in measuring accessibility to PT and LUDs.

The last one is the 'Metropolitan Accessibility and Remoteness Index of Australia' (Metro ARIA). This project was developed for Adelaide and Melbourne metropolitan areas to produce an index measuring accessibility and remoteness by the University of Adelaide (ABS, 2001). Metro ARIA is a composite index that aims to measure the ability of people to access basic services within the metropolitan area. It quantifies levels of accessibility by measuring the on-road distance people travel from their homes to reach different types of services. It incorporates five themes (health, shopping, PT, financial and postal, education) and component services that combine to produce the final index (GISCA, 2005). One weakness of the model is that it measures accessibility by road distances only, which favours road-based mobility with the motor vehicle as the preferred mode of travel.

Conceptual approach of LUPTAI

LUPTAI seeks to measure how easy it is to access common LUDs (e.g. health, education, retail, banking, employment) by walking and/or PT. This is in contrast to the traditional method of measuring accessibility by road or Euclidean distances, and is the first of its kind to consider PT as a means of access, rather than a facility to be accessed.

LUPTAI is an origin-based accessibility model. It has been produced via the use of GIS analysis techniques, applied to datasets obtained from a number of sources, and using information relating to LUDs, the road/pedestrian network, and the PT network. The model produces a GIS based map giving a visual representation of the opportunity to reach places by PT and/or walking. A five colour scale shows the levels of access for any given area, highlighting areas of ‘No, Poor, Low, Medium or High’ accessibility.

LUPTAI differs from the other accessibility models, as most of them conceive PT solely as a service to be accessed, and not as a means of potential access. It represents travel by modes other than the private motor vehicle and may be more useful in determining sustainable transport/land use outcomes. LUPTAI seeks to quantify accessibility to destinations via walking and the PT network. It considers walking in one of two ways: it may be either the single mode used to directly access a destination, or it may be the mode by which a person accesses PT services. Walking travel is measured in terms of actual distance, measured using the road and path network. In general, five minutes walking time is widely accepted as the equivalent to a 400 metre walk, assuming a walking speed of 80 m/min (O’Sullivan and Morrall, 1996; Department of Transport, 1999). It is also possible to convert walking distances to walking time, however the general tendency in transportation research is reporting walking travel as distance (Loutzenheiser, 1997; Shriver, 1997).

LUPTAI is an open source model which does not rely on a single GIS software package, unlike other models. The model performs its analyses using ESRI ArcGIS, however it can be run on other GIS packages (e.g. MapInfo) that have the capability to measure on-road distances (network analysis). Figure 1 below illustrates the details of the GIS-based LUPTAI flowchart.

During the developmental stage of LUPTAI, PT comprising of scheduled bus and rail services only were considered appropriate. Taxis, community transport and ferries were excluded, as were school bus services due to data availability issues. PT travel was measured in terms of travel time, derived directly from current timetable information. Walking distances to PT stops and LUDs are determined by examining current and previous household travel surveys (1992 and 2003/04).

The LUDs used in LUPTAI were:

- Employment: commercial zones (represent employment opportunities);
- Health: chemists, dentists, doctors and hospitals;
- Shopping: major shopping centres, newsagents (a measure of local shopping centres);
- Financial and postal:ATMs, banks, post offices;
- Education: primary, secondary and tertiary schools.

LUPTAI’s approach to trips is more realistic than other accessibility models. It considers a trip which starts from an origin and includes all trips taken to reach a destination; walking to a PT stop, PT travel, walking to a destination from a PT stop. LUPTAI also accommodates PT frequencies, which are incorporated in the PT layers (AM peak, off peak, PM peak, and evening). Moreover different PT service periods are associated with relevant LUDs. For example employment is measured with AM and PM peaks, representing the times that accessibility to employment is most needed.

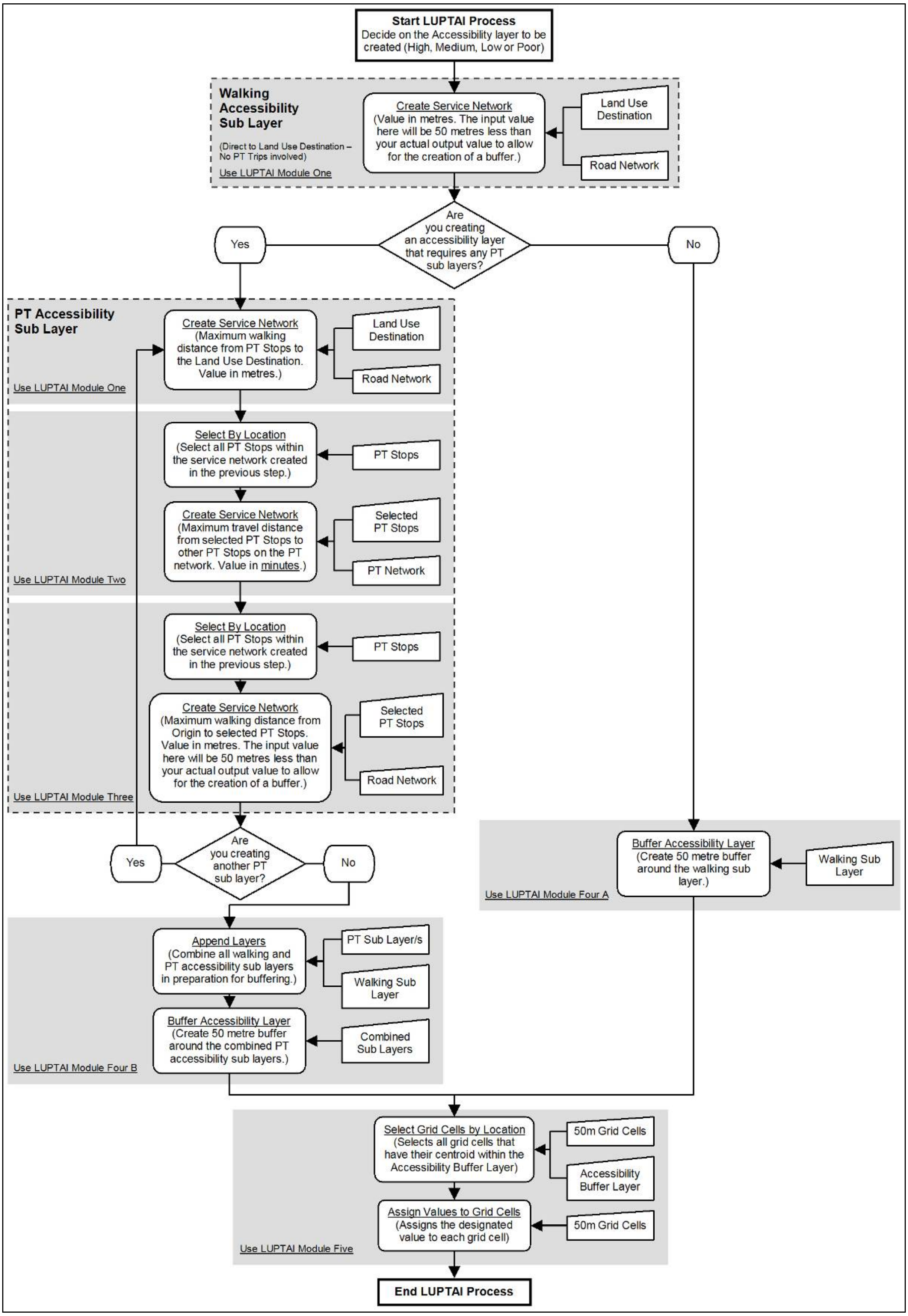

Figure 1: LUPTAI flowchart

Origin-based accessibility and destination-based GIS technique

LUPTAI seeks to quantify and determine the accessibility of a location by developing a composite index of measures. It uses a series of 'value measures' of accessibility for the purposes of quantification – these values primarily relate to travel distance and/or time measurements between two locations via the transport network. These measures are applied to data within a GIS, which allows for the manipulation of large quantities of spatial information necessary for such an analysis.

'Destination-based accessibility' focuses on accessibility of services such as shops, workplaces or schools, and 'origin-based accessibility' focuses on the accessibility of households to these services. This is based on the core concept that accessibility is a function of opportunity and deterrence. Origin-based accessibility analysis requires methods to measure the distances from origins to services via the transport network and also mathematical functions that define accessibility in terms of opportunity and deterrence. While LUPTAI is an origin-based accessibility model fulfilling this criteria, it accommodates a 'destination-based GIS technique' to simplify and provide significant computational advantages for LUPTAI. The destination-based GIS technique follows five logical steps (see Figure 2):

- Selecting PT stops (PTS-X in Figure 2) within a specific walking distance (400m for bus stops, 800m for train stations) from each destination (e.g. hospital).
- Selecting PT stops (PTS-Y in Figure 2) on PT routes that are within a given travel time (e.g. 0-20 min, 20-40 min) from PT stops (PTS-X) within the walking distance from each destination.
- Measuring and selecting road networks which are within a certain distance (e.g. 350m for bus stop, 750m for train stations) from these PT stops (PTS-Y).
- Applying a 50 metre buffer around the selected road network allows selection of the land parcels within 50 metres of the road network. This increases the measured distances from the origin to PT stops by 50 metres. The measured maximum distances from the origin to bus stops becomes 400 metres and for train stations this becomes 800 metres.
- Assigning an accessibility index value for the land parcels to represent these parcels' accessibility levels in regard to particular destinations (e.g. hospitals).

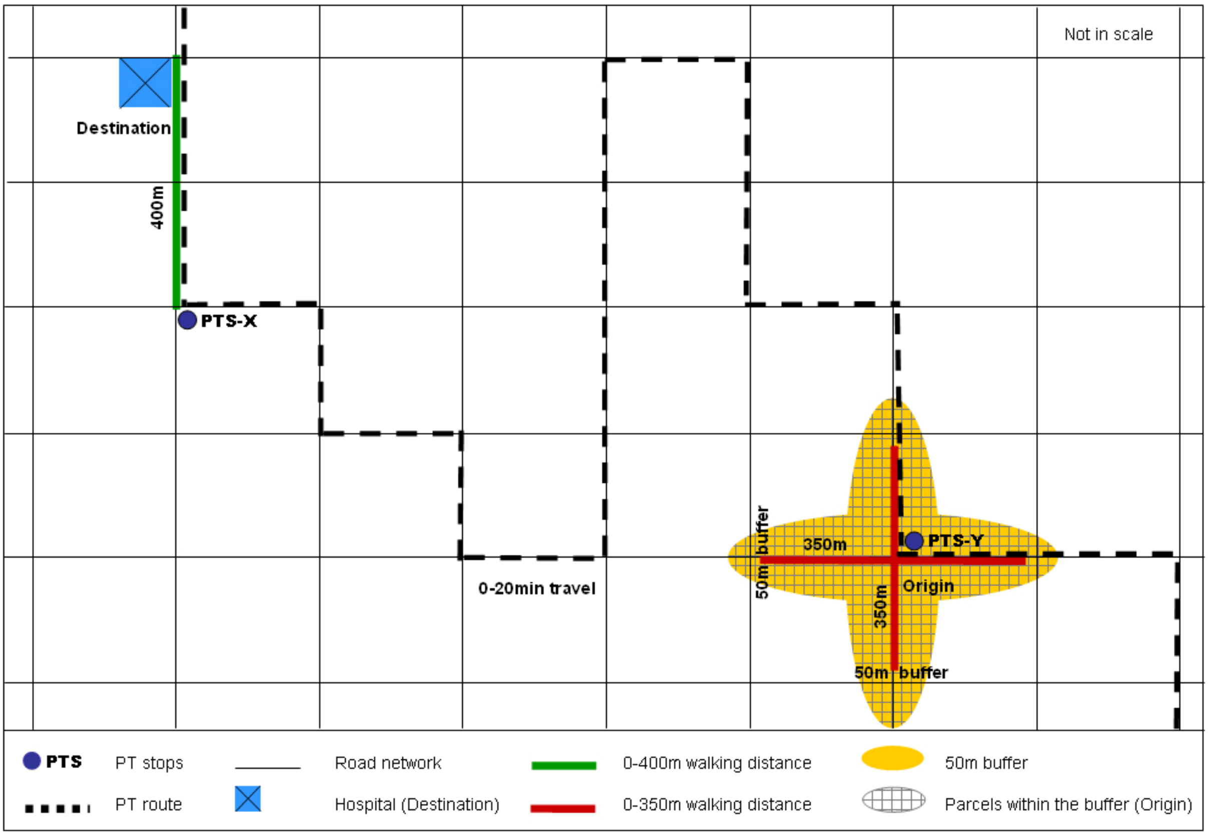

Figure 2: Schematic description of the destination-based GIS technique

Data related issues

Most accessibility models assess accessibility in a GIS environment. Obtaining accurate results in a GIS-based accessibility analysis relies heavily on the detail and quality of the input data (Zhu et al., 2005). An accessibility model requires information about land use and transportation systems. At a minimum land use data should contain the types of activities that exist and where they are located, and transportation data should contain information about transport networks, routes, stops and their frequencies.

Aggregate or city-wide accessibility analysis targeting a more strategic approach to accessibility requires less detailed data, compared to disaggregate or neighbourhood-specific analysis targeting a local planning approach. Generally data is readily available for basic characteristics of land use and transportation systems, however detailed quantitative data and data on qualitative and subjective factors is mostly scarce (Handy and Clifton, 2001).

Data availability is a major concern in any accessibility model as it can consume a significant part of project time and resources. Like most of the other accessibility models, LUPTAI uses GIS-based analyses and requires numerous datasets for the development of the necessary layers. These datasets include, but not limited to: transportation network (PT routes, stops, frequencies, road and pedestrian network), LUDs (e.g. hospitals), land use and zoning maps, census maps and travel behaviour maps (e.g. household travel surveys).

Using regularly updated datasets in LUPTAI is crucial for accurate accessibility modelling. Therefore in large projects that involves metropolitan/regional accessibility modelling (e.g. SEQ accessibility analysis), in terms of data integration, speed, cost, and licensing, it may be more practical if the data acquisition process is managed centrally (e.g. state or local government's transportation/planning department).

Accessibility measures

In the project development phase, various criteria were used to consider different access sensitivities for each type of LUD. For example trips to employment were modelled slightly different then other trips by using different accessibility measures.

LUPTAI accessibility measures were also developed to consider and allow for diverse choice options in personal trip-making, especially in terms of walking to a PT stop. This approach extends upon the standard walking distances to PT, which are often conceived as maximum trip-lengths of 400m (5min walk) to bus stops and 800m (10min walk) to train stations (i.e. Department of Transport 1999).

Accessibility measures within LUPTAI expand on the strict boundary limitations applied to walking in previous studies. This expansion improves accessibility measures in the index by allowing a degree of choice, between walking a short distance to PT for a long trip, and walking a longer distance to PT for a shorter trip. Walking distances to PT have been categorised into four distance-based categories: 'High, Medium, Low and Poor'. 1,200 metres (15min walk) is the maximum distance (limit to walking) applied within the health, shopping, financial and postal, and education accessibility measures. 1,600 metres (20min walk) is applied as the maximum walking distance for the employment accessibility measure. Walking distances at both ends of the trip are considered in the methodology (see Figure 2).

Several different options are explored for developing a more refined accessibility measure, which is based on enhancing existing accessibility models, and creating a new accessibility indexing methodology. The accessibility measures are displayed in Tables 1 to 3 and dealt with: (a) PT accessibility measures (for modelling the accessibility of the PT system, and integrating a service frequency measure into the index); (b) health, shopping, financial and postal, and education accessibility measures; and (c) employment accessibility measures. Tables 1 to 3 also contain matrices that display the accessibility of a parcel as determined by both the direct walking distance to/from PT, and by the PT frequency.

Table 1: Public transport accessibility measures

Layer	Mode	High	Medium	Low	Poor
Public Transport	Bus	Up to 300m walk & up to 10 min service freq	Up to 400m walk & up to 30 min service freq	Up to 800m walk & up to 60 min service freq	Up to 1000m walk & all running bus services
	Train	Up to 600m walk & up to 15 min service freq	Up to 800m walk & up to 30 min service freq	Up to 1000m walk & up to 60 min service freq	Up to 1200m walk & all running train services

BUS	Service Frequency (min)				
		≤10	30	60	>60
Walking Distance (m)	>0	H	M	L	P
	100	H	M	L	P
	200	H	M	L	P
	300	H	M	L	P
	400	M	M	L	P
	500	L	L	L	P
	600	L	L	L	P
	700	L	L	L	P
	800	L	L	L	P
	900	P	P	P	P
	1000	P	P	P	P
	1100	N	N	N	N
	1200	N	N	N	N
	1300+	N	N	N	N

TRAIN	Service Frequency (min)				
		≤15	30	60	>60
Walking Distance (m)	>0	H	M	L	P
	100	H	M	L	P
	200	H	M	L	P
	300	H	M	L	P
	400	H	M	L	P
	500	H	M	L	P
	600	H	M	L	P
	700	M	M	L	P
	800	M	M	L	P
	900	L	L	L	P
	1000	L	L	L	P
	1100	P	P	P	P
	1200	P	P	P	P
	1300+	N	N	N	N

H: High **M: Medium** **L: Low** **P: Poor** **N: None**

Table 2: Health, shopping, financial and postal, and education accessibility measures

Sub Layer	Mode	Walk to PT	High	Medium	Low	Poor
Chemists Dentists Doctors Hospitals Major Shopping Centres Newsagents ATMs Banks Post Offices Primary Schools Secondary Schools Tertiary Education	Walking	Direct, no PT trips involved	Up to 600m	600 – 800m	800 – 1000m	1000 – 1200m
	Bus	Up to 400m walk	N/A	Up to 20min travel time via PT	20 – 40min travel time via PT	> 40min travel time via PT
		400 – 800m walk	N/A	N/A	Up to 20min travel time via PT	20 – 40min travel time via PT
		800 – 1000m walk	N/A	N/A	N/A	Up to 20min travel time via PT
	Train	Up to 800m walk	N/A	Up to 20min travel time via PT	20 – 40min travel time via PT	> 40min travel time via PT
		800 – 1000m walk	N/A	N/A	Up to 20min travel time via PT	20 – 40min travel time via PT
		1000 – 1200m walk	N/A	N/A	N/A	Up to 20min travel time via PT

WALK (m)	>0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600+
	H	H	H	H	H	H	H	M	M	L	L	P	P	N	N	N	N

BUS	Travel time via PT (min)							
Walking Distance (m)	>0	10	20	30	40	50	60	70+
>0	M	M	M	L	L	P	P	P
100	M	M	M	L	L	P	P	P
200	M	M	M	L	L	P	P	P
300	M	M	M	L	L	P	P	P
400	M	M	M	L	L	P	P	P
500	L	L	L	L	L	P	P	P
600	L	L	L	L	L	P	P	P
700	L	L	L	L	L	P	P	P
800	L	L	L	L	L	P	P	P
900	P	P	P	P	P	P	P	P
1000	P	P	P	P	P	P	P	P
1100	N	N	N	N	N	N	N	N
1200	N	N	N	N	N	N	N	N
1300+	N	N	N	N	N	N	N	N

TRAIN	Travel time via PT (min)							
Walking Distance (m)	>0	10	20	30	40	50	60	70+
>0	M	M	M	L	L	P	P	P
100	M	M	M	L	L	P	P	P
200	M	M	M	L	L	P	P	P
300	M	M	M	L	L	P	P	P
400	M	M	M	L	L	P	P	P
500	M	M	M	L	L	P	P	P
600	M	M	M	L	L	P	P	P
700	M	M	M	L	L	P	P	P
800	M	M	M	L	L	P	P	P
900	L	L	L	L	L	P	P	P
1000	L	L	L	L	L	P	P	P
1100	P	P	P	P	P	P	P	P
1200	P	P	P	P	P	P	P	P
1300+	N	N	N	N	N	N	N	N

H: High M: Medium L: Low P: Poor N: None

Table 3: Employment accessibility measures

Sub Layer	Mode	Walk to PT	High	Medium	Low	Poor
Commercial Zone	Walking	Direct, no PT trips involved	Up to 800m	800 – 1000m	1000 – 1200m	1200 – 1600m
	Bus	Up to 300m walk	Up to 20min travel time via PT	20 – 30min travel time via PT	30 – 50min travel time via PT	> 50min travel time via PT
		300 – 400m walk	N/A	Up to 20min travel time via PT	20 – 30 min travel time via PT	30 – 50min travel time via PT
		400 – 800m walk	N/A	N/A	Up to 20min travel time via PT	20 – 30min travel time via PT
		800 – 1000m walk	N/A	N/A	N/A	Up to 20min travel time via PT
	Train	Up to 600m walk	Up to 20min travel time via PT	20 – 30min travel time via PT	30 – 50min travel time via PT	> 50min travel time via PT
		600 – 800m walk	N/A	Up to 20min travel time via PT	20 – 30min travel time via PT	30 – 50min travel time via PT
		800 – 1000m walk	N/A	N/A	Up to 20min travel time via PT	20 – 30min travel time via PT
		1000 – 1200m walk	N/A	N/A	N/A	Up to 20min travel time via PT

WALK (m)	>0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700+
	H	H	H	H	H	H	H	H	H	M	M	L	L	P	P	P	P	N

BUS	Travel time via PT (min)							
Walking Distance (m)	>0	10	20	30	40	50	60	70+
>0	H	H	H	M	L	L	P	P
100	H	H	H	M	L	L	P	P
200	H	H	H	M	L	L	P	P
300	H	H	H	M	L	L	P	P
400	M	M	M	M	L	L	P	P
500	L	L	L	L	L	L	P	P
600	L	L	L	L	L	L	P	P
700	L	L	L	L	L	L	P	P
800	L	L	L	L	L	L	P	P
900	P	P	P	P	P	P	P	P
1000	P	P	P	P	P	P	P	P
1100	N	N	N	N	N	N	N	N
1200	N	N	N	N	N	N	N	N
1300+	N	N	N	N	N	N	N	N

TRAIN	Travel time via PT (min)							
Walking Distance (m)	>0	10	20	30	40	50	60	70+
>0	H	H	H	M	L	L	P	P
100	H	H	H	M	L	L	P	P
200	H	H	H	M	L	L	P	P
300	H	H	H	M	L	L	P	P
400	H	H	H	M	L	L	P	P
500	H	H	H	M	L	L	P	P
600	H	H	H	M	L	L	P	P
700	M	M	M	M	L	L	P	P
800	M	M	M	M	L	L	P	P
900	L	L	L	L	L	L	P	P
1000	L	L	L	L	L	L	P	P
1100	P	P	P	P	P	P	P	P
1200	P	P	P	P	P	P	P	P
1300+	N	N	N	N	N	N	N	N

Methodology of application

LUPTAI measures accessibility by utilising a destination-based GIS technique (see Figure 2). LUPTAI consists of: (a) measuring accessibility based on walking distances; (b) measuring accessibility based on PT travel time; and (c) combining both accessibility measures and assigning accessibility index values to each grid cell, which is a 50 metre to 50 metre area used for spatial analysis.

Figure 3 illustrates a schematic description of the methodology. First, accessibility levels to LUDs (e.g. hospitals) are measured using walking distances (i.e. 600, 800, 1,000 and 1,200m). Next accessibility levels are measured using PT travel times (i.e. for bus 0-20min, 20-40 and 40 plus). Then these two values are merged to form accessibility levels of the land parcels to selected LUDs. The label of 'None' represents areas which are not accessible via PT and walking modes, and thus did not fall into 'Poor, Low, Medium or High' accessibility categories. The details of the application of each measure via the computing process are in five steps.

- A network analysis is performed on the road/pedestrian network to determine the level of accessibility to the LUD from other land parcels.
- The nearest PT stop is determined by running network analysis on the road network.
- PT travel time analysis is conducted on the PT network to find the locations that could be reached (catchment area) from the destination land use for a given travel time. This identifies and selects PT stop locations within the catchment area.
- The road/pedestrian network is selected for given walking distances from these selected PT stops. Once the road/pedestrian network has been selected, a buffer area is drawn around this network highlighting the 'accessible' land parcels.
- The highlighted land parcel's accessibility values are then transferred to a 50m grid that is placed across the urban area for ease of display and analysis. The grid files showing the accessibility of each 50m grid square to the LUDs are then available for the creation of a composite index map providing a measure of accessibility to all destinations.

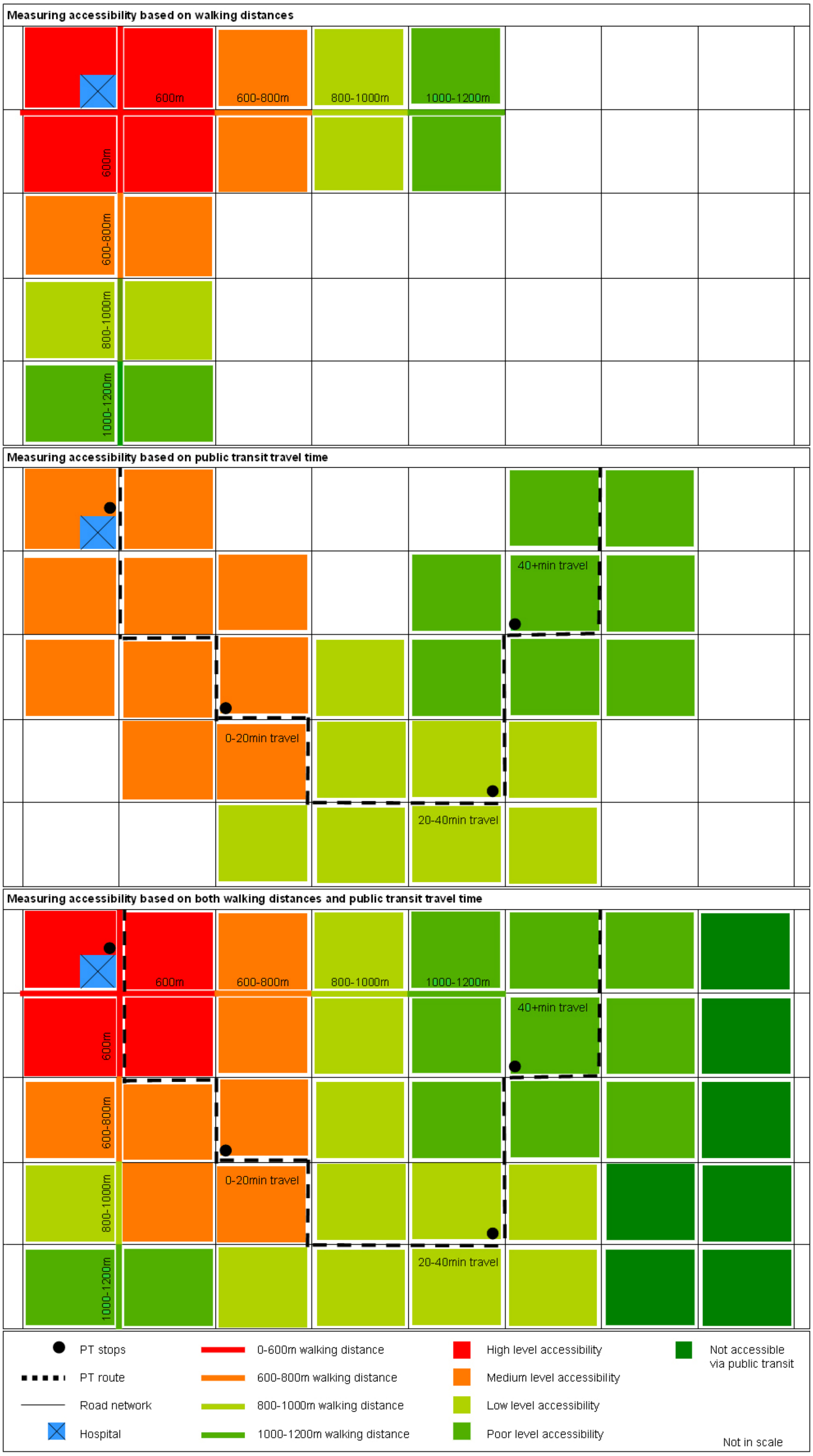

Figure 3: Schematic description of the methodology

Weightings and the development of composite indices

LUPTAI's methodology allows measures of accessibility to be displayed both in terms of geographic accessibility, which is purely spatial, and demographic accessibility, which is spatial information weighted to population density.

The geographic accessibility measure is a composite index that provides an accessibility measure for all selected LUDs. The composite index assumes that each layer (i.e. education, health, shopping) is weighted equally, which reflects a top-down model. Figure 4 shows how the sub-layers were weighted to achieve these outcomes.

Each sub-layer within the index was firstly combined with one or more PT layers to add a frequency measure to each sub-layer, which could affect a person's travel behaviour. The PT layers chosen for each sub-layer were based on when people would generally access each service.

Alternative weighting options were also considered. One alternative was to create an equal weighting bottom-up model, where each LUD (and its overall PT layers) would be given an equal value and the index would be built up in a similar fashion to the top-down model. This option was not used because the index would have been unduly influenced by particular layers, i.e. health and financial and postal, which are not necessarily the most important.

Another option was considered which attempted to reflect actual travel behaviour. This alternative index was weighted on the basis of travel behaviour using household travel survey database. However in most of the Australian metropolitan areas the distribution of household trips to employment and shopping constitutes more than half of all trips. When these figures are converted into composite index weightings, shopping and employment layers comprise more than three quarters of the index. Because these two land uses dominated the index it was decided that the equal weighted top-down model would be the preferred model used in LUPTAI.

The demographic accessibility measure is a population weighted accessibility index. Population density is used in grid cells instead of population to avoid assigning population on non-residential uses such as parks and large vacant lands. Population densities (number of persons per square kilometre) are transferred from census collection districts to 50m grid cells by using the spatial analysis extension feature of the GIS software – ArcGIS.

The use of this population weighted accessibility index is intended to identify areas where there is a major imbalance of accessibility vs. population density. Areas deemed to have a comparative level of accessibility and population density should not automatically be excluded as an area where increases in population density or accessibility are not needed. This index should also be used in conjunction with the composite (non-population weighted) index to identify areas with inadequate accessibility.

This approach allows for the measurement of accessibility per capita for a given area and is also potentially useful for local government land use and transportation planning purposes. Using these two approaches the methodology produces a reasonable measure of accessibility.

There are two effective ways of displaying population density with LUPTAI. The first is to combine population density values with the values from the composite map to provide a population-weighted index. The second is to display the composite index on a three-dimensional map that uses population density as the third dimension (i.e. height) through use of the 3D analyst extension feature of ArcGIS.

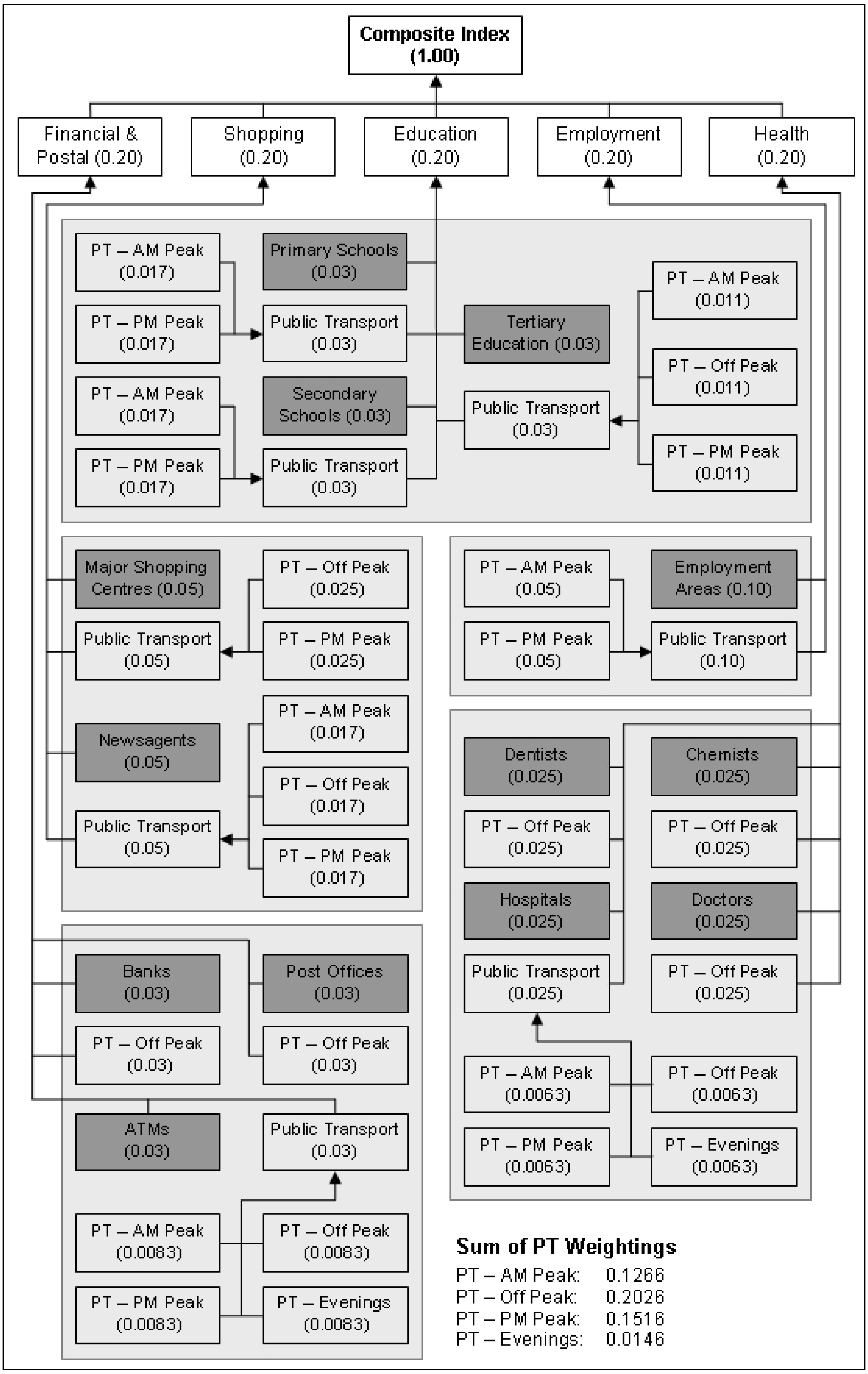

Figure 4: Composite index weightings – equal weighting top-down model

Assumptions and limitations

Several assumptions are made in order to run LUPTAI more accurately. These assumptions are grouped into four categories: residential travel behaviour, conceptions of the PT network, conceptions of LUDs, and conceptions of the road/pedestrian network. While these assumptions slightly reduce our capacity to measure accessibility levels precisely, they ease the complexity of LUPTAI.

The first set of assumptions relate to the demographic profile of residents and their travel behaviour. LUPTAI does not take into account any differences in residents' social, economic, physical and travel preferences. It assumes that any person, regardless of their ability or social standing, will have equal opportunities to access PT services. LUPTAI only estimates whether a person has access to a particular service; it does not take into consideration a person's preferences to travel further to obtain the same type of service, good or opportunity. LUPTAI also focuses on the 'nearest' single LUD and does not provide a measure of accessibility to two or more such land uses. It should also be noted that LUPTAI measures accessibility, not proximity to a LUD.

The second set of assumptions relate to the PT network, which is modelled in a relatively simplified manner. Due to the complexities involved, the model precludes interchange of PT trips between different modes of travel. However the model includes interchanges from one bus to another bus service and from one train to another train service. Similarly, only weekday PT service frequencies were incorporated into the analysis. It is assumed that all bus routes will stop and pick up passengers at every stop on the designated route, even though some of the routes are express only and buses on those routes stop only at express stops. In addition, LUPTAI models each separate bus route separately that does not accurately reflect the cumulative effect of more than one bus route running along the same street.

The third set of assumptions relate to how LUD data was sourced and coded for the analysis. There are no formal definitions for certain LUDs (i.e. major shopping centres, major employment centres), and no datasets available other than via somewhat inventive research methods. The use of derived definitions to identify the final set of such destinations may generate minor errors, although these may be resolved through local knowledge and/or ground truthing.

The fourth and final set of assumptions relate to the road and pedestrian network. The datasets obtained do not include a large number of walking tracks or paths, both formal and informal, which are known to exist. The analysis used in this study also allows for access via streets where pedestrian prohibitions exist (e.g. highways).

Major limitations of LUPTAI's methodology relate primarily to data availability and accuracy. Some of the major limitations include:

- GIS is a data hungry analysis model, thus all required datasets need to be available and manipulated into simplified forms to achieve the best results;
- Due to the way GIS software performs its analyses there is the potential for both operator and system errors that require manual checking of each map layers;

- LUPTAI conceptual framework and analysis is primarily designed for application in urban areas – alterations to the methodology should be considered prior to applications in rural areas;
- LUPTAI includes only walking and PT modes in estimating accessibility – it does not take into account private automobiles, taxis, ferries, community transport or cycling;
- LUPTAI does not consider the influence of topography, design (e.g. shaded or not) or walking environment (e.g. walking in a park or next to a busy road) in estimating accessibility;
- The size of grid cells within LUPTAI is limited by processing time and the file size of the grid (e.g. a 50m grid takes at least four times longer to process and is four times larger in file size and area than a 100m grid).

Pilot studies

LUPTAI can be used as a planning support model at two levels: aggregate and disaggregate levels. To test and demonstrate the benefits of LUPTAI in different applications/scales of the planning process, two pilot studies were undertaken.

The first pilot study is undertaken at an aggregate/city-wide or strategic level, which focuses on the whole Gold Coast City Council local government area (LGA). The intent was to use LUPTAI to inform the development of Gold Coast's Local Growth Management Strategy (LGMS), in particular, to promote future urban growth (both infill and greenfield development) within areas of high accessibility in order to achieve integrated transport and land use planning.

The second pilot study is undertaken at a disaggregate/neighbourhood-specific or local level. A master planned case study site within the Gold Coast LGA was analysed. At this scale LUPTAI was used to test development/transport scenarios to assist with the development assessment process.

Aggregate level accessibility analysis

Implementing LUPTAI at the aggregate or strategic level should result in better decision making about future land use and transportation facilities. LUPTAI can help to shape strategic policy, including LGMSs, Priority Infrastructure Plans (PIPs), and corridor alignment studies.

Local governments are required to complete an LGMS by June 2007 as required by the SEQ Regional Plan. LGMS's are intended to enable each local government to demonstrate how it proposes to achieve the dwellings targets and other key urban development policies set out in the SEQ Regional Plan, based on detailed local investigations.

There is great scope to deliver the transport and land use outcomes outlined in the Regional Plan at the local level via LGMS's. The application of LUPTAI on the Gold Coast provides a mechanism to influence the development of the LGMS to deliver integrated transport and land use outcomes through a partnership approach between Queensland Transport and Gold Coast City Council. LUPTAI is informing Gold Coast's LGMS development in the following ways:

- Highlight areas for potential transit-oriented development;

- Highlight areas with high accessibility due to PT provision and land use mix where it would make sense to consider increasing population densities;
- Highlight areas where low accessibility exists where it would make sense to improve PT provision and/or land use mix;
- Identify areas of social exclusion and transport disadvantage;
- Co-locate future urban growth around future major PT investments in the LGA;
- Assess the current draft PIP growth assumptions;
- Sequence urban growth with provision of major PT infrastructure and services.

PIPs provide local councils with a means of integrating infrastructure and land use. LUPTAI helps planners by clearly identifying areas with low accessibility and quantifying the number of people that are affected. The pilot project has shown that LUPTAI could benefit the prioritisation of infrastructure investments. Population weighted indices (see Figure 6 and 7) are particularly useful for developing funding priorities (i.e. prioritising infrastructure staging), as they contain both accessibility and population density figures.

Corridor alignment projects aim to develop integrated land use-transport strategies. These strategies focus on key elements of transport infrastructure, which have the potential to prompt changes in land use patterns with resultant social, economic and environmental benefits. LUPTAI takes key LUDs, residential densities, major employment centres – particularly in major activities centres and mix use development, walking and PT. These are fundamental components of an effective integrated land use and transport strategy. Thus LUPTAI has the potential to be applied to corridor alignment projects such as the Caboolture to Maroochydore Corridor.

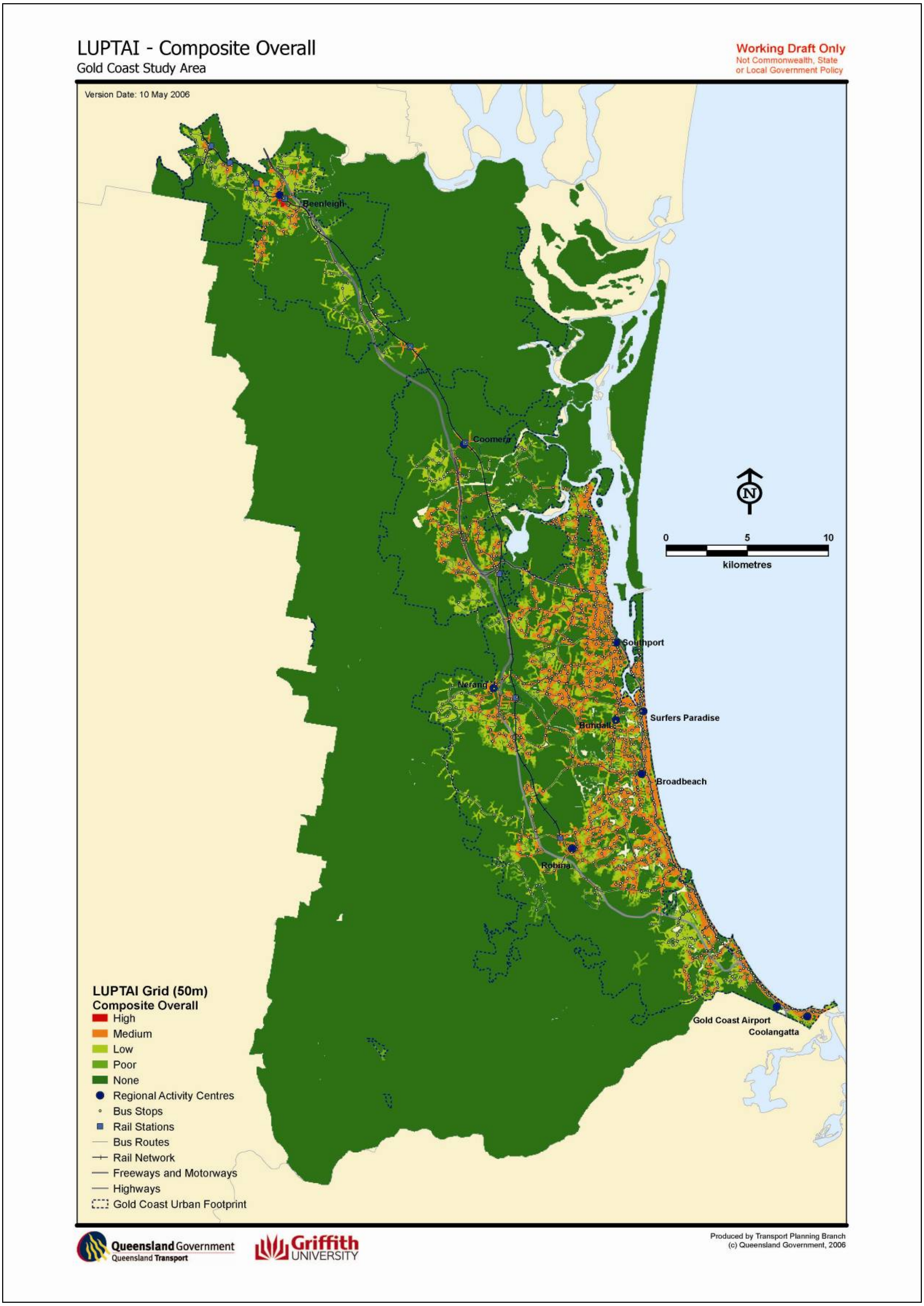

Figure 5: The Gold Coast LUPTAI composite index

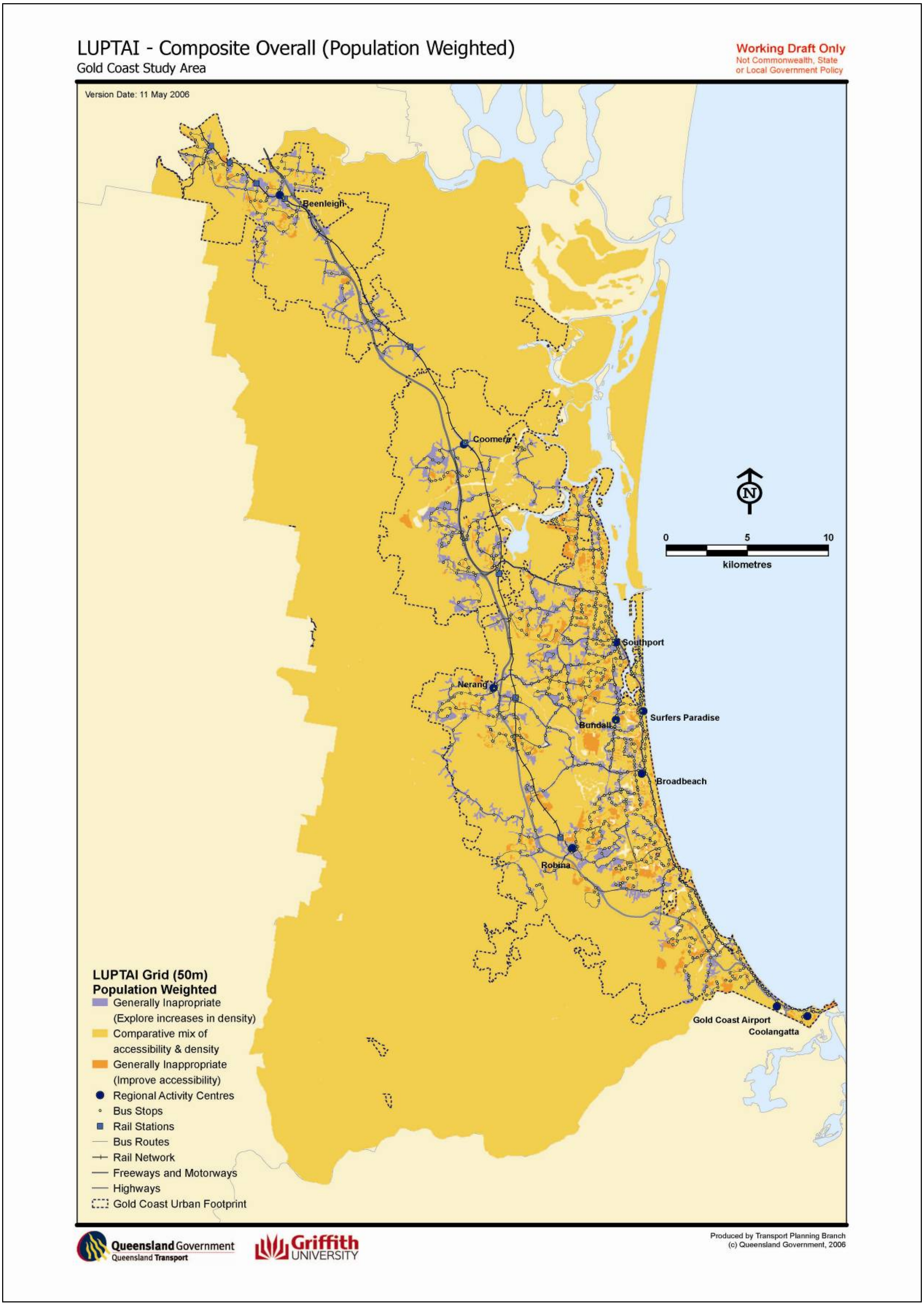

Figure 6: The Gold Coast LUPTAI population weighted composite index

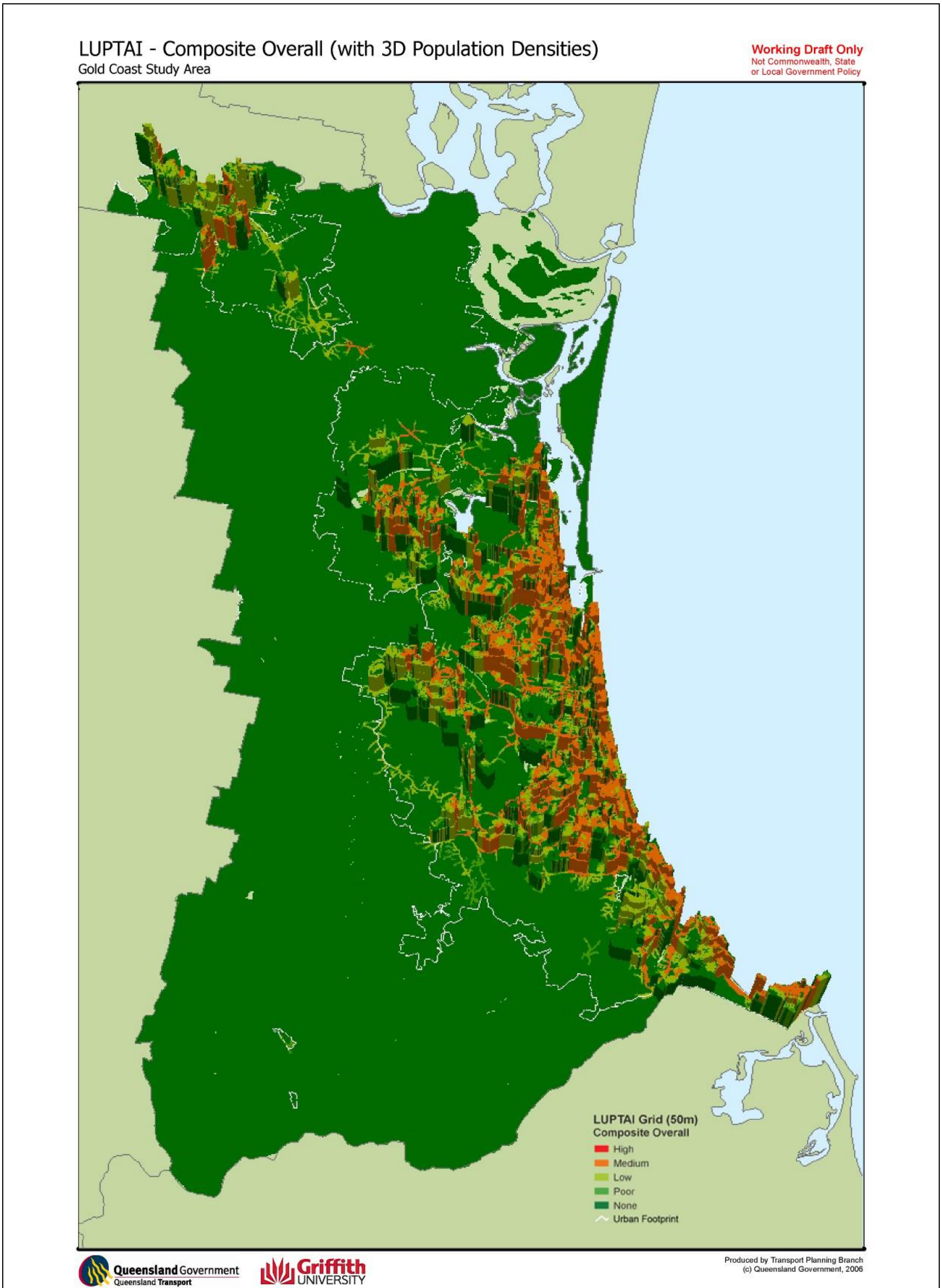

Figure 7: The Gold Coast LUPTAI composite index with 3D population densities

Disaggregate level accessibility analysis

LUPTAI is emerging as potentially an important value adding model at disaggregate or local level (i.e. to the development and assessment of structure plan and master plan sites). LUPTAI provides the means to test various development and PT scenarios using quantitative data and visual mapping to assist local government and/or the developer optimise a development application.

The second pilot study was undertaken to test the feasibility of using LUPTAI for assessing future master planning developments. A case study was selected from the Gold Coast LGA and focused on a medium-high density development proposal for 10,000 people.

LUPTAI was run several times in order to evaluate the accessibility of the master planned site. Instead of providing a precise accessibility assessment of the proposed development, this analysis should only be viewed as an exercise to test the capabilities of LUPTAI.

The pre and post-development accessibility levels of the case study site (both population weighted and non-population weighted indices) were calculated using LUPTAI (Figures 8 to 10). LUPTAI results helped to focus attention on those areas with low accessibility. Figure 9 illustrates the population weighted composite accessibility assessment for pre-development scenario. By using this map, we were able to target certain parts of the project area and implement policies for increasing accessibility level. The results also provided the basis for suggesting improvements, both within and surrounding the study area, to increase accessibility. Some of the most obvious improvements included:

- The creation of a bus route and associated stops through the pilot study area;
- Upgrading service frequency of the existing bus route in the area;
- Adding a new bus stop on an existing route;
- Constructing a new pedestrian bridge;
- Upgrading a pedestrian bridge to a vehicular bridge.

After the suggested improvements listed above were added to the development proposal, LUPTAI was rerun and the results showed a significant increased in the levels of accessibility (Figure 8 and 10).

The learnings from the second pilot indicates that LUPTAI can add value to the planning and assessment of master planned and structure planned sites to achieve:

- Integration of land uses with existing and future committed PT infrastructure/services;
- Connective street networks that promote pedestrian activity and facilitate future PT connections;
- Appropriate mixture of land uses;
- Appropriate densities to take advantage of the high levels of accessibility produced.

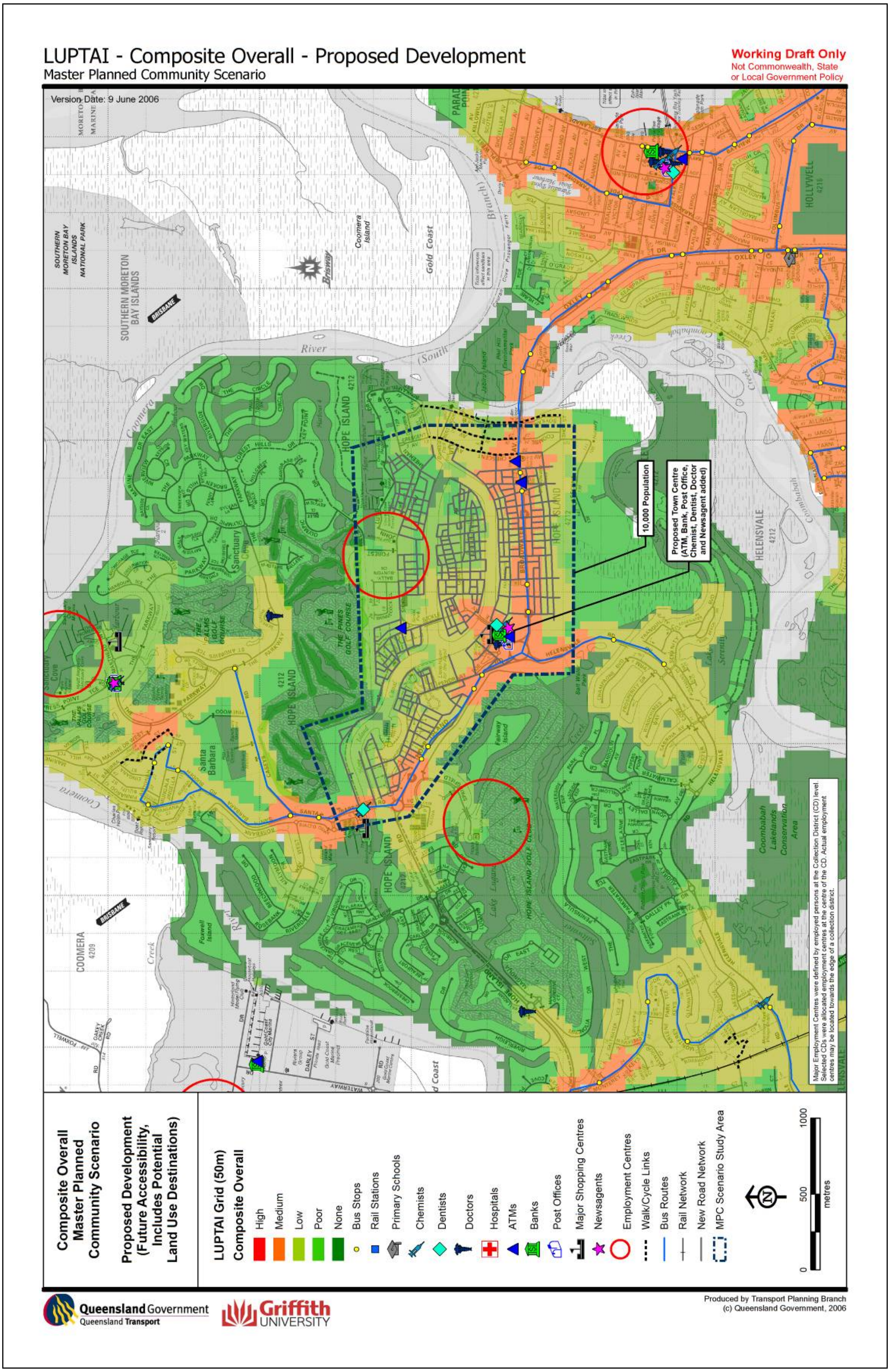

Figure 8: LUPTAI overall composite index – proposed development

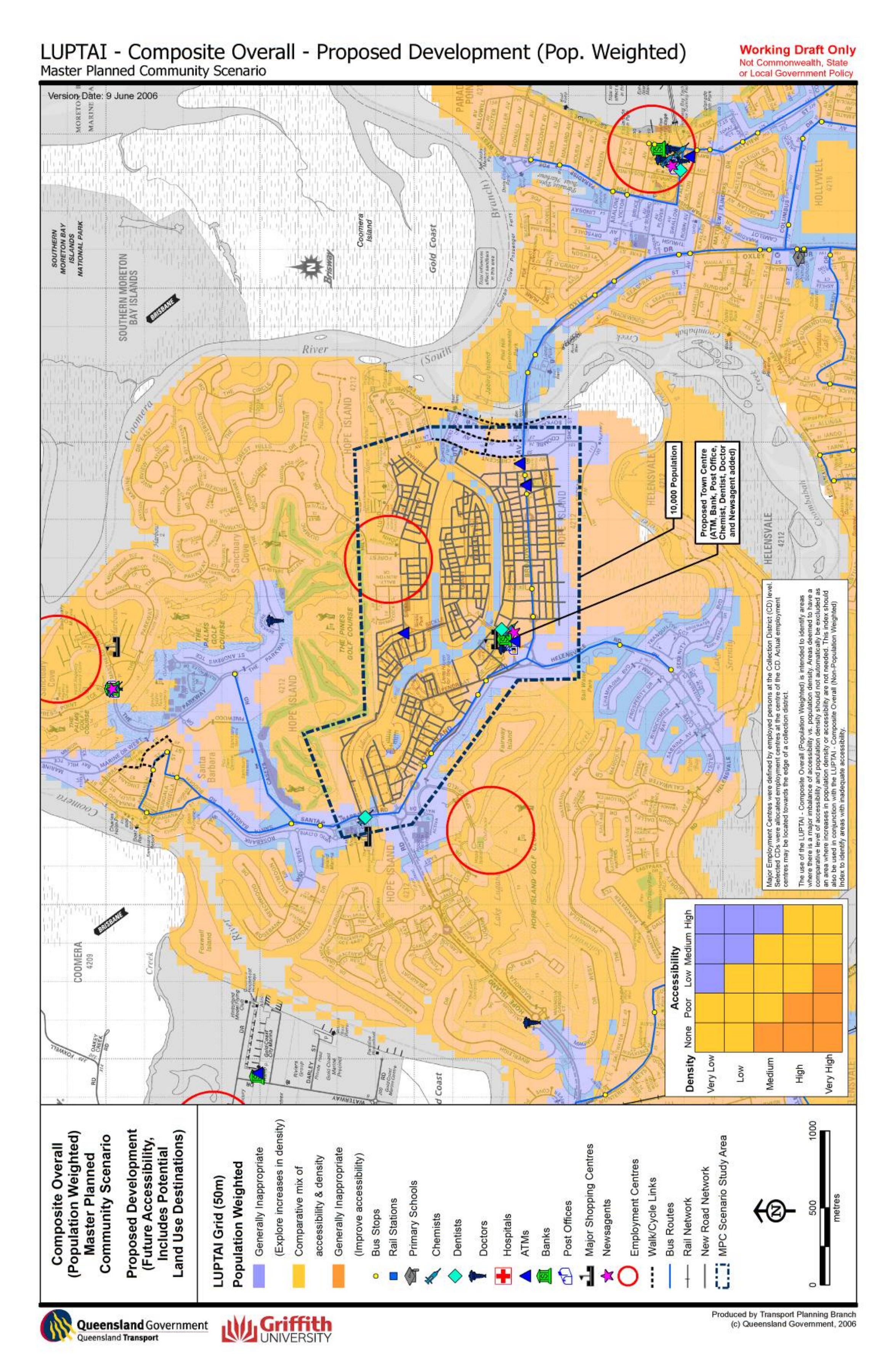

Figure 9: LUPTAI population weighted composite index – proposed development

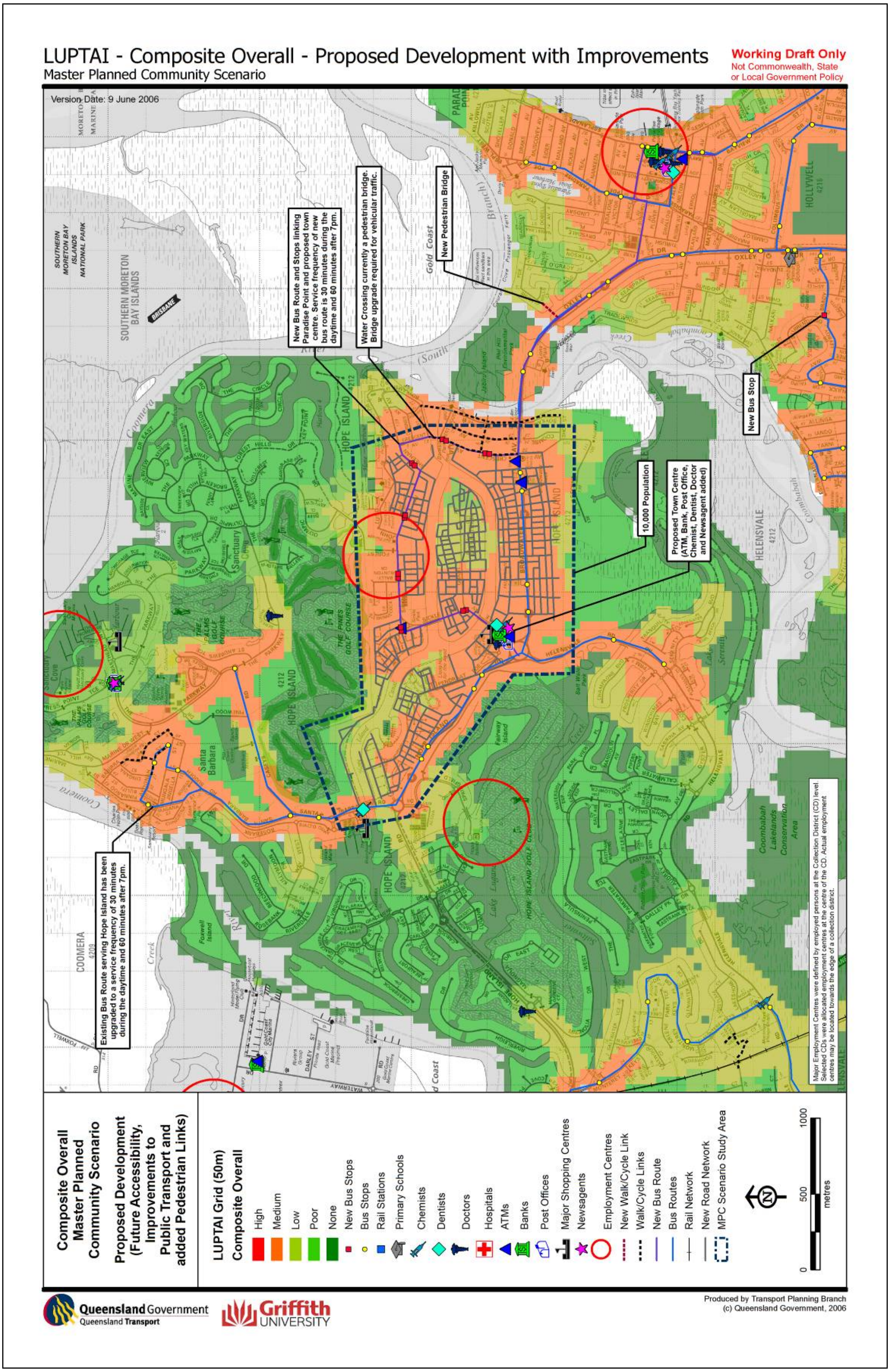

Figure 10: LUPTAI overall composite index – improved proposed development

Conclusions

The research results demonstrate it is possible to produce a viable accessibility model, apply the model to a major urban area (e.g. the Gold Coast LGA), and to produce a mappable accessibility index. This has been achieved within the data collection and resource constraints of a small research team with transport/land use planning and GIS capacity.

Methodologically, the theoretical constructs and procedures developed were recognised by the Queensland Transport as generating significant advances in measuring and displaying critical transport/land use relationships. It is believed LUPTAI produces sufficient sensitivity to clearly identify areas with higher accessibility levels and areas with lower accessibility levels. This sensitivity is demonstrated most effectively by the composite map (see Figure 5), that is of considerable use to transport and land use planning decision-makers.

Through an iterative process, accessibility measures have also been developed and improved upon to provide sufficient sensitivity and more accurately represent human travel behaviour decisions. The ground-truthing processes suggest that the results produced for the Gold Coast LGA reflects the reality observed in an on-the-ground survey.

This research has shown LUPTAI is a valuable accessibility model for both state and local government in land use and transport planning tasks. LUPTAI can assist state government with shaping its policies, and identifying infrastructure and servicing requirements to cater for future urban growth. Local government would benefit with better decision-making for LGMS, PIPs, structure plans, master plans, development assessment and as a monitoring model.

LUPTAI is a flexible model that can be customised (i.e. consider other modes and other LUDs) and adapted to best suit the requirements of state and local government in their land use and transport planning processes.

The pilot projects have demonstrated the use of LUPTAI as a planning support model that can ensure urban growth is sequenced and co-located with existing and future PT projects to achieve integrated transport and land use planning outcomes that:

- Reduce the need to travel and the length of trips;
- Promote social equity by providing travel choice and promoting sustainable travel modes;
- Utilise existing infrastructure and services (i.e. PT, water, energy) and minimise the need for new infrastructure;
- Support local business and activity centres.

The pilot project also revealed LUPTAI is capable of determining accessibility levels for a large number of LUDs. Currently up to 22 different layers are used in LUPTAI (13 LUDs, PT routes, PT stops, 4 PT service periods, road network, pedestrian links, and population densities).

The authors' further research will focus on enhancing LUPTAI by including more LUDs such as activity centres, regional recreation areas, social, cultural and religious centres and locations of transport disadvantaged people. The model will be refined further by including inter-modal interchanges, school bus services and routes, PT weekend peak services, and express bus stops. Other potential alterations to LUPTAI will include modifying its methodology to include private motor vehicle and bicycle trips. Moreover manual adjustment for pedestrian links and locations of major employment centres at the disaggregate level are among the improvements to be explored in future refinements of LUPTAI.

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