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Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS)

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Background

The Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) accessibility instrument was developed to fill a significant gap in planning for accessibility by providing a planning support tool that can be used to inform strategic land use and transport planning. Its first application was in providing a comparison of metropolitan accessibility by public transport for three centres within Greater Perth, Western Australia. Following this use it became clear that our instrument could be applied in a wide range of settings. As a result our research over the past five years has focussed on its use to support government decision making on re-structuring of metropolitan urban form to support public transport (and vice versa) and developing a twenty year investment strategy for public transport services and new infrastructure. To answer these types of questions we realised that the instrument needed to be developed in a way that could forge constructive collaborations between transport and land use planning agendas. The tool needed to have a function of trans-disciplinary communication in order that land use transport integration be fully understood and achieved. A focus on accessibility can introduce land use considerations into conventional transport models, and conversely, land use planning can be enhanced by better understanding of the mobility implications of particular urban forms. It was also important for us to develop an instrument whereby the dissemination of accessibility measures through visual media offered a means to enhance understanding, making a contribution towards a productive discourse on future directions for urban form and mobility, engaging a wide range of stakeholders and thus helping to bring this important challenge further into the public arena.

Conceptual framework and theoretical underpinnings

SNAMUTS is a GIS-based tool to assess the relationship between public transport network configuration, performance and service standards on the one hand, and the geographical distribution or clustering of land use activities across a metropolitan area on the other hand.

SNAMUTS breaks down the land use-transport system into a set of activity nodes and route segments derived from the hierarchy of activity centres identified in strategic planning documents, and the location and service standard of public transport routes. In particular, SNAMUTS makes the following definitions:

Minimum service standard: SNAMUTS defines a *minimum standard* for inclusion of a public transport route into the analysed network, requiring a service frequency of 20 minutes (or better) during the weekday inter-peak period (about 10.00 to 15.00) and 30 minutes (or better) during the day on Saturdays and Sundays. This level has been chosen as it reflects the minimum for public transport to be perceived as having a full-time presence and attracting usage for a variety of both planned and spontaneous journey purposes. More specifically this approach aims to set public transport accessibility on a level playing field with accessibility by car, thus providing the real possibility for the traveller to choose between modes. In so doing this sets a standard for design of the future transport service (and land use patterns) where accessibility by public transport is possible for as many travellers across the metropolitan area as possible (where accessibility by public transport is the objective of governments).

Activity nodes: these refer to the list of higher-order activity centres across a metropolitan area (principal, major and specialised) that appear in strategic planning documents such as Melbourne 2030 and Melbourne @ 5 million or Perth's Network City and Directions 2031. There are also some major transfer points and some linear corridors along high-frequency tram or bus lines captured where they play an important role in the network. In some cases, a designated activity centre may contain more than one SNAMUTS *activity node*.

Each *activity node* is assigned an exclusive catchment of residents and jobs located within walking distance from the associated rail station(s) (800 m) or tram/bus corridors (400 m). Wherever two or more of these catchments overlap geographically, the residents and jobs are distributed in equal parts among the associated *activity nodes*. In effect, every resident and job within walking distance from a minimum-standard public transport service has been assigned to one, and only one, *activity node* catchment.

Travel impediment: SNAMUTS measures spatial separation, or spatial resistance (a proxy value for distance) by relying on the units that are closest to the public transport user experience, namely travel time and service frequency. Each route segment is labelled with an impediment value consisting of the average travel time divided by the number of services per hour, separately for each direction, and multiplied by a factor of 8 to arrive at more readable numbers. The travel impediment (proxy distance) between any two activity nodes on the network is thus made up of the sum of the impediment values on each route segment passed along the path. Another indicator adds to this by considering the transfer penalty on public transport (see below).

Operational aspects

SNAMUTS utilises six indicators (see Curtis & Scheurer, 2010) including:

Closeness ***centrality*** describes the ease of movement along the public transport network, in terms of speed and service frequency.

Degree centrality describes the directness of journeys along the public transport network. It is a topological network indicator, measuring the minimum number of transfers between each pair of activity nodes.

Contour catchments measure the combined effect of public transport speed and land use intensity. This index determines the number of residents and jobs within the walkable catchment areas of activity nodes that can be reached within a public transport travel time of up to 30 minutes from the reference node.

Speed comparison measures the competitiveness of public transport against the car. The index determines the travel time ratio between public transport and road travel (in typical congested conditions) for the path between each pair of nodes.

Betweenness centrality captures the geographical distribution of attractive travel paths between each pair of nodes across the network. It shows concentrations of 'movement energy' generated by the travel opportunities the network provides, or in other words, to what extent an activity node is located 'at the crossroads' of public transport supply. It essentially identifies those transport routes that will be traversed the most (cumulatively) by journeys between different pairs of centres after all potential journey combinations are considered.

Nodal connectivity measures the strength of each activity node for (multimodal) integration of services. It captures the suitability of activity nodes for making transfers or breaks of journey with minimal disruption to the flow of movement.

Composite indicator for overall public transport accessibility is compiled from the figures for each of the above indicators. They are converted to a scale from approximately 0 to 10 to afford them roughly equal weighting. Higher values indicate greater accessibility. The composite index is commonly visualised on a scale map of the metropolitan area, highlighting the geographical catchment areas of each activity node in traffic light colours according to their composite score.

Two further measures can be drawn from the SNAMUTS database and are utilised to highlight network characteristics that facilitate comparisons between cities or along time lines within the same city.

Service intensity describes the number of vehicles for each mode that are in simultaneous revenue service during the reference period. It is given as a total as well as relative to metropolitan population. Service intensity is a two-sided measure: it illustrates both the generosity (or not) of a public transport operator or agency to provide operational resources, and the efficiency of their dispatchment. Thus the ratio between service intensity changes and shifts on the accessibility measures can help to determine the efficacy (or not) of initiatives to expand (or cut) public transport services.

Network coverage is an aggregate, network-wide indicator of the previously described contour catchment measure, extracted by overlaying all defined activity node catchments and then counting the percentage of metropolitan residents and jobs contained within them. Network coverage can illustrate the growth (or shrinkage) over time of the proportion of the metropolitan area that is accessible by public transport services of the SNAMUTS minimum standard, and can benchmark this proportion for comparisons between cities.

The evolution of public transport accessibility over time is also captured in the *global and local efficiency change index*. This index delivers a percentage figures for the improvement (or deterioration) of public transport accessibility at each activity node (local efficiency), as well as for the network as a whole (global efficiency), following changes in service levels, network configuration and/or land uses. It does this by comparing the minimum travel impediment (closeness centrality) for each pair of nodes, weighted by the product of the number of activities (residents and jobs) at either node, before and after the changes.

Most recently, a *network stress index* has been developed that takes in the aforementioned segmental betweenness index and draws a ratio with the actual quantitative ability of the public transport service to move passengers. This index is designed to highlight where in the network the concentration of travel opportunities generated by the land use-transport system appears to outstrip, match or remain below the carrying capacity offered by the transport mode(s) and service levels on the route segment in question (Scheurer & Woodcock, 2011).

Relevance for planning practice

SNAMUTS identifies and visualises a land use-public transport system's strengths and weaknesses in a coherent mapping exercise, considering geographical coverage; ability and efficiency to connect places of activity; strategic significance of routes and network nodes; and, speed competitiveness between public transport and car travel.

The SNAMUTS tool has so far been applied in several collaborative ventures with land use and transport planning agencies as well as academic partners in Perth, Melbourne, Hamburg and more recently Porto and Copenhagen (Scheurer, 2009; Scheurer, 2010).

In Perth, the completion of a 72-km radial suburban railway in late 2007 provided an opportunity to test the SNAMUTS model on a real-life, before-and-after comparison of network performance and service levels, as well as the broader role of public transport in the mobility mix of the Western Australian capital. Our analysis demonstrated how accessibility by public transport changed across the metropolitan region, with effects beyond the simple view of improvements along the new railway itself. In addition, the analysis highlighted the way in which improvements to network accessibility open up considerable possibilities to improve land use opportunities at locations with improved accessibility (Scheurer & Curtis, 2008).

By developing an interactive decision tool we assisted in the examination of scenarios for activity centres framed around the accessibility of the transport network and the accessibility of place. Testing these factors through a scenario approach enabled key planning questions to be examined:

- Which activity centres could best be intensified?
- Which centres should perform a regional role and which ones a local role?
- Where should public transport investment (infrastructure, service improvement) go?

The data and ideas being fed into SNAMUTS were drawn from work in progress within the agencies. This research project as well as the earlier accessibility ranking data informed the next iteration of the metropolitan planning strategy and the outcome has been the release of the 'Directions 2031' strategy (Curtis & Scheurer, 2009).

A project for the State Public Transport Authority (PTA) in 2010 employed SNAMUTS to evaluate the PTA proposals) for the next 20 years investment in public transport for greater metropolitan Perth. The PTA in developing their strategy wanted to test how well the proposed network and service performed in relation to enhanced public transport accessibility to key activity centres.

In 2009 SNAMUTS has been used to benchmark public transport accessibility between cities – Melbourne and Hamburg (Scheurer, 2009). SNAMUTS was used to determine how the public transport networks in both cities are configured, how responsive they are to the geographical distribution and concentration of residents and jobs across the urban structure, and how capable to provide accessibility and convenience of travel across the metropolitan area.

SNAMUTS is a tool designed to assess the impact of network and land use changes in the past and the future. This is the case regardless of whether such changes are the outcome of deliberate planning efforts such as policy decisions to expand or cut public transport service or to pursue transit-oriented development schemes, or of self-regulated processes such as the deterioration of service quality due to traffic congestion or market-led urban development along or away from public transport facilities. SNAMUTS was again used as a comparative tool for longitudinal analysis along the recent example of the introduction of an orbital bus service (Route 903) through Melbourne's middle suburbs in April 2009.

Strengths and limitations

The relative accessibility of activity centres and network nodes can be determined by SNAMUTS and used to inform decisions about both public transport network configuration and about land use intensification in the catchment areas of nodes and corridors that gain in accessibility. This tool is well-suited to inform local area planning to add detail to the strategic directions spelled out in a metropolitan planning strategy, and to identify gaps in public transport service that need to be addressed to achieve the congruence of movement and land use the document aspires to. It is also well-suited to inform priorities for the future expansion of public transport infrastructure in the Perth metropolitan region.

SNAMUTS planning decision support tool has been employed by using a discursive approach, in a way not common to the development or use of traditional transport models. Indeed where research has been conducted into the utilisation of knowledge derived from analytic planning techniques it is apparent that there is little evidence of its use or effectiveness by decision-makers (Sager & Ravlum, 2005). In recognising this problem, our aim was to design SNAMUTS in such a way that it could be easily understood and 'owned' by decision-makers as a means to utilisation in decisions. SNAMUTS design, including the simple rationale in measuring the network from the personal traveller perspective and the use of visual mapping outputs, is aimed at promoting deliberative processes that can be appreciated by a wide range of users, not just those with mathematical modelling expertise.

In terms of the usefulness of SNAMUTS, workshop participants have indicated that its value goes beyond simply providing knowledge on public transport networks or future urban form. While SNAMUTS demonstrated the possibilities for measuring public transport accessibility, some of the highest ratings were for the use of the tool in governance—especially the value of the tool in communicating decisions to the public and in aiding collaboration across the professional groups. In commenting on the particular SNAMUTS indicators, workshop participants indicated the two greatest strengths were the visual composite maps (Figure 1) and the way in which speed of travel by public transport and car travel can be compared. The interviewees added to this indicating that by seeing accessibility plotted provided the department with measurements, before this they had relied on anecdotal evidence. They also noted that when the transport outcomes were mapped it became clear that there had not been, but needed to be, a land use response where accessibility had not improved.

Participant's also identified—'its ability to explore supply-led scenarios'; the way in which it generates an index of accessibility, noting that this was based on theoretical connectivity rather than actual use; and the way it 'is easier to recalibrate for differing scenarios'. In relation to the traditional transport models, one noted that there was 'no comparison, different purposes'.

We continue to develop the instrument, in particular we are applying it to cities around the world as part of a project looking to inform the Australian government as to an appropriate benchmark for public transport accessibility in order to inform infrastructure investment and priorities.

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Figures

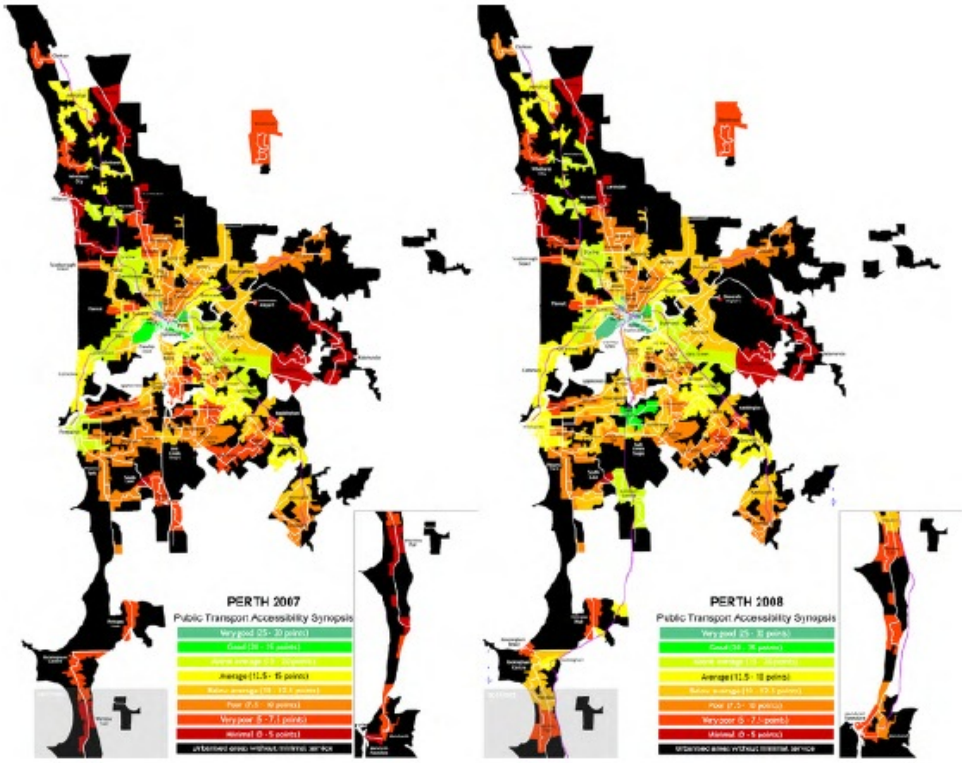

Figure 1 SNAMUTS visual output clearly shows accessibility changes with the implementation on a new rail corridor and a bus network reconfigured to act as a feeder service.