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Spatial Network Analysis of Public Transport Accessibility (SNAPTA)

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Background

SNAPTA has been designed to evaluate the spatial accessibility and the social equity of an urban public transport system. Currently, it has been applied to the Edinburgh transport network to analyse i) the spatial accessibility and equality in the distribution of urban services, and (ii) the impact that planned transport projects in the Local Transport Strategy will have on spatial accessibility by public transport. It, therefore, is used for both *ex post* and *ex ante* evaluation of public transport services.

Good accessibility is seen by the Scottish Government as a driver to economic growth and competitiveness through "providing access to markets and enhancing the attractiveness of cities as focal business locations and tourism" (Scottish Executive, 2004: 18). In the National Transport Plan accessibility is linked to *improving journey times and connections* and to the *quality and affordability of public transport choices* (Scottish Executive, 2006:2). Accessibility is translated into the Edinburgh Local Transport Strategy as "whether or not people can get to services and activities at a reasonable cost, in reasonable time and with reasonable ease". (CEC, 2007:82).

Previous empirical studies of accessibility in the study area have examined the sub-regional context, or wider travel to work context, using an aggregated dataset to make broad-brush statements about accessibility. Halden (2002) examined the accessibility outcomes of different strategies for growth and David Simmonds Consultancy used a computer model to predict the impact of two major new strategic headquarters developments to the west of Edinburgh beyond the city bypass close to the airport (Bramley *et al.*, 2011). More recently, Jan Scheurer has been examining sub-regional accessibility using the SNAMUTS model.

Conceptual framework and theoretical underpinnings

SNAPTA is GIS based accessibility instrument which defines accessibility as "whether or not people can get to services and activities at a reasonable cost, in reasonable time and with reasonable ease". Three measures or indicators of accessibility are used:

Time access to city centre by public transport from each zone during the actual morning peak hour travel to the Central Business District (CBD).

A contour measure which calculates the total number of economic activities or destinations within a maximum travel time by public transport for different trip purposes.

A potential accessibility measure. A gravity-based measure using the morning peak hour travel time between data zones, weighted by the quantity of activity opportunities per zone. Using Hansen's equation [$A_i = \sum_j a_j . f(t_{ij})$], the potential accessibility for the residents of each origin zone A_j is estimated. Where a_j is the attractiveness (quantity or size of activity points) of destination zone J, t_{ij} is travel time, cost or distance from zone i to zone j, and $f(t_{ij})$ is an impedance function. The impedance function adopts a low value for the sensitivity parameter [β] with a value of 0.1 since people using public transport are not very sensitive to a small variation of time (Boucq, 2007; Spiekermann and Wegnener, 2007).

The instrument, therefore, focuses on the land use and transport component of urban interactions and the availability of opportunities during the morning peak hour which can be accessed by public transport. The above-mentioned indicators have been widely used in the literature and they rely on different methodologies to measure accessibility. The fundamental difference between them is that the time access to city centre and contour indicators focus on the separation between locations while the potential indicator focuses on the interaction between locations (Gutiérrez *et al.*, 1996). The selection of accessibility indicators used in SNAPTA depends on the objectives of the instrument user .

The theoretical underpinnings of the potential accessibility measure are that the interactions between an origin and destination will decline with increasing distance and time but that interactions are positively associated with the amount of activity at each location (Hansen, 1959). The instrument focuses on groups of people, and assumes that they have a set of social and economic activity needs to be met at different destinations, and that travel demand will be determined by the attractiveness of these locations and the quality of the transport infrastructure linking these places.

Operational aspects

SNAPTA uses the UK Census Data Zones, which have a population of 500-1000 residents, so that contextual data on the population and socio-economic criteria can be used. Land-use and socio-demographic data (at Data Zone level) including the total number of jobs, total gross floor area of retail services and recreation facilities, and number of patients in health care centres and hospitals, can be obtained under licence from government organisations. The data on the number of students in secondary schools and universities, and number of leisure and recreation facilities can be obtained from these organisations' websites.

The digital multimodal transport network of bus services, tramways and railways can be modelled in GIS (ARC/INFO). The network covers the whole of the studied area and consists of links and nodes. The nodes are chosen on the network to correspond to boarding points which provide a regular coverage across the study area. The analysis involves the closest node on each public transport route (within the zone) to the zone's centroid. The centroids of larger, lower density zones of the periphery of the urban area are re-calculated on the basis of population origins.

For each transport link in the GIS data base, tabular attributes of its type, length and the time needed to pass that link have been built. SNAPTA takes into account walk access time, waiting time, in-vehicle time and interchange time. In-vehicle travel time through each link belonging to the currently running transport services can be calculated based on the timetables associated with the bus and tram stops or railway stations during the morning peak times.

Accessibility is calculated for the time access to city centre based on the shortest journey time (or the fastest possible route) by public transport from the nearest node (boarding point) in the network to the centroid of each zone to the nearest node to the centroid of the CBD. The shortest possible journey time might be achieved by using one or more services whether those services are provided by the same type of transport mode or not. The calculation of the potential accessibility indicator is more complicated. It also involves the shortest possible journey times on the network using public transport from the nearest node to the centroid of each zone as an origin to those nodes nearest to the centroids of the other zones as destinations. Once the travel time is computed for each relationship, the accessibility value of each origin zone will be obtained by relating the travel times with the land use attractiveness values (opportunities size) in the destination zones by applying Hansen's equation. A contour indicator has also been measured for each zone by calculating the size of desired opportunity (land use attractiveness) that can be reached by using public transport from that node in the network nearest to the zone centroid within the determined maximum time. A maximum travel time of 15 minutes applies to trips for shopping purposes, while a length of 30 minutes is used for other services, since having a choice of retail services such as a supermarket is not as significant as the choice within recreational and educational services. In a GIS environment, the outputs of SNAPTA can be mapped and demonstrated in 3D using Interpolation and 3D Analyst techniques to show the spatial distribution of accessibility across the modelled area.

Data collection and input into GIS database is a quite time-consuming process while, by comparison, running the SNAPTA instrument in GIS does not take a long time. However, data input and performing the calculation require a good knowledge of GIS software including ArcCatalog and ArcMap especially the functions of ArcGIS Network Analyst (i.e. Cost Matrix, Closest Facility, Service Areas and the Best Route) that are used to run the accessibility calculation. With regard to the degree of expertise required to interpret a SNAPTA output, it depends on the choice of accessibility measure. The results of the potential indicator are not easy to interpret by non-modellers as they are expressed in units while those of the contour indicator and time access to the CBD represent the number of reached opportunities and the needed travel time respectively, which are easy to interpret.

Relevance for planning practice

This instrument has only just been designed so it has not yet been used by public or private sector decision makers. Both the City of Edinburgh transport department and the Lothian Region Health Board were involved in

early stages of the design of the instrument. The intention is to work with these institutions to refine the instrument to their specific needs. The instrument will be useful to service providers in several ways;

SNAPTA compares the zonal accessibility by public transport and can estimate the accessibility impacts brought about by proposed transport infrastructure changes. In the case of Edinburgh, it can evaluate the zonal impact of route choices for new infrastructure such as the tram.

At a strategic level, it provides an overview of the attractiveness of zones accessed by public transport to identify the "hotspots" of activity during the morning peak hour. This locates areas of potential congestion which may require specific management approaches.

At a strategic level, it can identify at a disaggregated level those zones that are relatively poorly served by public transport. This can be correlated with income and car ownership data to identify where the public transport system needs strengthening.

At a service operational level, when disaggregated by activity, the instrument shows the length of public transport commute for residents using the isochrones feature.

At a service operational level, the instrument can show the likely zonal impact of service closure and relocation (e.g., Hospital).

Accessibility is one of the UK government's *ex ante* evaluation criteria for transport project proposals in that the impact on accessibility is one of the key criteria for (i) the assessment of major development proposals in the UK and (ii) the assessment of major transport infrastructure projects by the Department of Transport and Transport for Scotland. Current appraisal methodologies are limited to assessing the impacts of development or transport infrastructure on the surrounding neighbourhood roads. SNAPTA, therefore, introduces a focus on the spatial equity by public transport.

Strengths and limitations

One of SNAPTA's drawbacks is that zonal centroids are used, and so SNAPTA assumes that all individuals are gathered at the centroid and enjoy the same level of accessibility, although they have different travel demands and may perceive the set of alternatives quite differently. In addition, since Data Zones are groups of 2001 Census output areas have populations of between 500 and 1,000 residents, however, the areas of some zones are very large compared with the rest due to their low population density. Therefore, generating the same accessibility value for the whole area of a large zone is questionable. Another drawback is that the opportunities which are located just outside the modelled area even by only few seconds are neglected. Assuming a walk time between origin or destination and boarding point of 10 or 15 minutes (based on the zone size) rather than calculating the actual walk time through the pedestrian network can be considered as a weakness. Also, the input of the required transport data into a GIS environment is a quite time consuming process.

On the other hand, the key strength of SNAPTA is the ability to apply a package of accessibility indicators using small geographical divisions, and with different ranges of land-use and socio-demographic data. Therefore, the instrument takes into account both transport and land-use systems for accessibility analysis. Since three different types of accessibility indicators are applied in SNAPTA, the results can be used for different applications in transport and land-use planning. Another benefit of including different accessibility indicators is the ability to tackle a limitation of one of the applied indicators by using another indicator in the package. For example, no distance decay is considered in the contour indicator (i.e. all the opportunities located within the selected maximum travel time area are equally counted and not weighted by the distance) while the potential accessibility indicator applies a gradual decay in the distance. The potential indicator considers all the relationships between all origins and destinations while the considered area is limited by using the contour indicator. Also, the results of potential indicator are not easy to interpret by non-modellers as they are expressed in units while the contour indicator output represents the number of reached opportunities which is easy to interpret.

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Figures

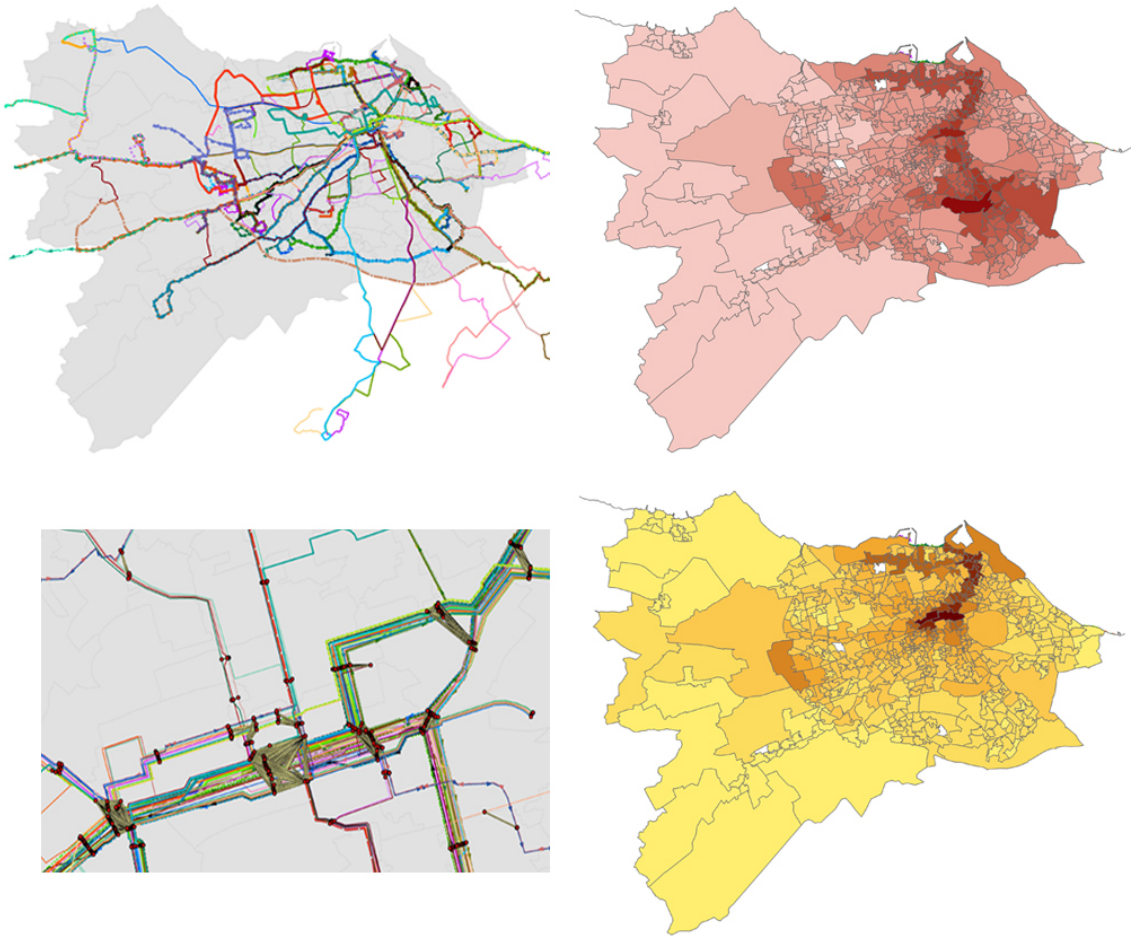

Figure 1 Left- Modelling of public transport routes. Right- Mapping of potential accessibility indicator result