Access envelopes: A new accessibility mapping technique for transport and settlement planning

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Abstract

The article describes the application of a GIS-based accessibility measurement technique suited to assessing the impact of both transport and spatial development strategies on the location-specific affordability of job access for poor households. The access envelope methodology extends existing accessibility measures by: explicitly accounting for public transport service patterns; including transport costs as a dimension of accessibility; and deriving a single intuitive measure of access reflecting the potential income earnable by a person living in a certain location, after paying for transport. Several case studies from the City of Tshwane are presented, illustrating its use for assessing spatial integration and transport initiatives. The cases demonstrate how Tshwane's emerging Bus Rapid Transit (BRT) system selectively enhances accessibility to jobs, although its marginal accessibility benefit is reduced by the part-duplication of existing rail lines to core employment areas. While the BRT improves the net earning potential of low-income workers in certain areas, its ultimate benefits will significantly depend on its achievement of network effects – especially via the reduction of first/last-kilometer trip costs – and its ability to leverage higher density development within walking distance of the route. Accordingly, results obtained with the access-envelopes method carry significant implications for current transport planning in the main metro cities.

'N NUWE TEGNIEK OM DIE TOEGANKLIKHEIDSIMPAKTE VAN VERVOER- EN NEDERSETTINGBEPLANNING TE KARTEER

Die toepassing van 'n metode om die toeganklikheidsimpakte van beide vervoer- en ruimtelike ontwikkelingstrategieë op die haalbaarheid van werksgeleenthede onder lae-inkomste huishoudings te beoordeel, word bespreek. Die metode is gegrond op Geografiese Inligtingstelsels (GIS), en verbeter bestaande metodes om toeganklikheid te meet deur openbare vervoerdienste direk in ag te neem; vervoeronkostes as a dimensie van toeganklikheid in ag te neem; en 'n enkele intuïtiewe indeks te ontwikkel om die potensiële inkomste van 'n person wat op 'n bepaalde plek woon, te bereken, inaggenome die koste en tyd wat aan vervoer bestee word. Gevallestudies van die Stad Tshwane word aangebied om die toepassing van die metode te illustreer. Die gevalle toon die mate waartoe Tshwane se opkomende Snelbusstelsel toeganklikheid tot bepaalde werksgebiede kan verbeter, ten spyte daarvan dat die inkrementele voordeel beperk word deur die feit dat die busstelsel bestaande treindienste gedeeltelik dupliseer, veral ten opsigte van bestaande kerngebiede in die stad. Die snelbus verbeter wel die netto potensiële inkomste van werkers, maar sy voordele sal uiteindelik afhang van die mate waartoe die kostes van die eerste/laaste kilometer van ritte verminder word, en die mate waarin verdigting en ontwikkeling in areas wat binne loopafstand van die roete is, behaal word.

ACCESS ENVELOPES: THEKENIKI E NCHA YA HO BEHA MMAPENG MEKHOA E BOBEBO YA TRANSPOTO LE MERERO YA BOLULO

Serapa sena se hlalosa tshebediso ya thekeniki ya ho fumana sohloe ha bobebe ka GIS, e sebedisetsoang ho sheba na transpoto le tswediso pele ya dibaka tse kholo di ama hakae mabapi le ho fhla mesebetsing ha bonolo le ho se utlloisi pokotho bohloko. Access envelope methodology e sarolla mekhoa ya ho fihla dibakeng tse hlokahalang ha bonoloka ho sebetsana le ditshebeletso tsa transpoto, haholo holo ditefello tsa transpotoya sechaba e le mokhoa oa ho bebofatsa ho fihla dibakeng tse hlokahalang le ho fana ka mokhoa o le mong oa ho fihla ha bobebo dibakeng tse hlokahalang o ipapisitseng le se motho a se kholang. Dipatlisiso tse ngata tse tsoang City of Tswane di bontsha tshebetso ya bona ya ho shebisisa kenyelletso ya dibaka le traspoto. Dipatlisiso di bontsha lka mokho Bus Rapid Transit (BRT) e thusitseng batho hore ba fihle mesebetsing ka nako teropong ya Tswane, le ha ho fihla ha bobebe ha eona ho ts'iroa ke diterene tse ne se ntse di le teng. Le ha BRT e ntlafatsa chelete ya batho basa kholeng haholo, ditla morao tsa eona tse hantle di ka thusoa ke ditefiso tse tlase le ho phahamiso trswelopele ya bona pela batho hore ba khona ho tsamaya ka maoto hofihla ho yona. Ha ho le joalo access envelopes method e bontsha ho eba le diphetoho tsa merero ya transpoto ka hara teropo tse kholo.

1. INTRODUCTION

The links between spatial policy, housing, and transport are at the heart of many of the current urban development policy debates. Continuing urban migration, coupled with stagnant economic growth and enduring housing backlogs, puts pressure on government to accelerate housing delivery programmes as part of its anti-poverty strategy. Previous housing programmes oriented towards delivery of subsidized single dwellings in peripheral locations have been criticized for perpetuating spatial exclusion and increasing travel costs to households (e.g. Behrens & Wilkinson, 2003: 154; Cross, 2008). Thus, current policy prioritises delivery of a wider range of housing options in a wider range of locations: Cabinet's Outcome 8 for human settlements, for instance, aims to upgrade 400 000 shack units on 'well-located land', by which is generally meant land in closer proximity to economic and social opportunities. Such locations typically impose higher land and

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housing costs on the state and/or the household. Thus a key trade-off in the articulation of spatial development policy is that between housing costs and transport costs. This trade-off is especially pertinent to metro cities where widespread adoption of Bus Rapid Transit (BRT) initiatives (Moosajee, 2014) requires transport-planning decisions, which will have major effects on near-term transport expenditure and on future urban land use.

Access and mobility are central to the character of settlements insofar as their ability to promote sustainable livelihoods is concerned. Access – especially of the kind delivered by walking and by public transport – helps determine labour absorption and social well-being. Several studies in the StepSA suite highlight the constraining relation of urban transport to urban migration, settlement, and access to the labour market (Venter & Cross, 2011: online; Cross & Ngandu, 2014: 198). Improving decision-making with respect to settlement planning thus requires the simultaneous evaluation, in a common framework, of both spatial and transport conditions and interventions.

The StepSA project aimed, in part, to promote more integrated approaches to spatial decision-making. The divide between transport and spatial analysis is not necessarily caused by data problems. Spatial data is proliferating, driven by the combination of new geosensing technologies and better analysis methods. Geographic Information Systems (GIS) have provided analysts with powerful tools for extracting relationships and presenting findings. Accessibility analysis is among the most promising approaches in this regard, and is founded on a long history of scholarship. It has seen some application in South Africa (see for instance Green et al. in this volume), but, as discussed below, suffers from some methodological limitations.

By describing the use of a GIS-based technique, the access-envelope technology is applied to address some of these limitations through a series of illustrative case studies from the City of Tshwane Metropolitan Area. Case studies include a comparison of the accessibility benefits offered by two competing settlement locations, and an illustration of the impact of underemployment on earning potential. The technique is used to investigate (and visualize) the potential improvements in accessibility to jobs that can be secured through the implementation of specific transport projects such as a BRT route. These results carry significant implications for current transport planning in the main metro cities.

2. ACCESSIBILITY CONCEPTS

Accessibility is broadly defined as the ease of reaching desired destinations from a particular location, given a number of available opportunities and the difficulty (or impedance) of reaching them. Usually, opportunities are measured in terms of employment positions, and impedance in units of distance or time. Accessibility is thus determined by three main elements: land use, transport, and the individual characteristics of the person.

There has been a revival in interest among scholars in accessibility both as a theoretical construct and as a potential spatial planning tool. This is partly attributable to a conceptual shift among transport and spatial planners from focusing on mobility (i.e. the ability to travel) towards a focus on accessibility (i.e. the ability to participate in activities) (Cervero, 2005: 1; Zegras, 2011: 570-571). Accessibility is often distinctly linked to notions of equity and social justice, on the basis that accessibility deficits may lead to social exclusion and the denial of basic human rights (Martens, 2006; Jaramillo, Lizárraga & Grindlay, 2012: 342). In a review of the effectiveness of urban transport interventions in East Africa, Howe (2000: 12) notes that “it is the ‘accessibility’ that a transport system provides which is of fundamental importance to the extremely poor”.

2.1 Accessibility measures

Attempts to develop practical applications of the concept of accessibility have generated a large amount of literature on accessibility measures and indicators (Koenig, 1980; Geurs & Ritsema van Eck, 2001). Most of this work has focused on measuring accessibility by car (El-Geneidy & Levinson, 2006: online), but there has lately also been increasing interest in measuring access levels for non-motorised transport users (Iacono, Krizek & El-Geneidy, 2008) and public transport users (e.g. Delmelle & Casas, 2012: 36; Cheng & Agrawal, 2010: 55).

Although accessibility measures can be classified in several ways, of particular interest to this work are two broad classes of approaches, namely gravity-type measures and threshold-type models. First suggested by Hansen (1959), gravity-type measures sum all available opportunities in a study area, but weigh each according to a function of the travel impedance to reach them. Thus, opportunities located closer to the point of origin ‘count’ more than opportunities further away. Recent applications of the technique in developing countries include the use of a gravity-type index to measure the extent to which a new BRT system enhanced access to activities for different income groups in Cali, Colombia (Delmelle & Casas, 2012: 36-46). Venter & Mohammed (2013: 4) used a gravity-type index based on travel distance to measure the accessibility to jobs in various parts of Nelson Mandela Metropolitan Area.

An advantage of this class of measures is that it does not require the analyst to specify an arbitrary cut-off distance or travel time: all potential destinations are considered. But the choice of deterrence function – in essence a reflection of how quickly activities lose attractiveness as they become more difficult to reach – is not straightforward. The complexity of gravity indices also makes them more difficult to interpret by decision-makers.

Threshold-type measures, by contrast, specify a cut-off value and only count the number of opportunities that are located within that boundary. Examples include catchment or contour analyses, which count the number of job opportunities a person can reach from a given home location within a specific commute time. Researchers at the CSIR (CSIR, 2007; Maritz, 2008) have used this technique to examine the physical accessibility of South African communities to social services and to identify locations where the supply and demand of facilities are not balanced, based on acceptable service provision standards (i.e. maximum travel distances or times).

Tiwari & Jain (2012: 87-95) took a similar approach to measuring the accessibility benefits of the Delhi BRT, by calculating the number of destinations (by type) that are within reach of different types of road users, and the number and type of users for whom this metric has increased (compared to the pre-BRT situation).

2.2 Accessibility measures limitations

A common shortcoming in the way accessibility measures of both types have been applied to date is the simplistic way in which travel impedance is measured. Partly due to data scarcity, travel disutility is most commonly measured using travel distance and travel time. These are often estimated from road network data, as detailed data on public transport routes and services are not available. When the intention is to reflect the accessibility enjoyed via public transport – desirable when analysing low-income communities – this situation is clearly untenable. Qualitative work for the StepSA project has indicated to what an extent actual taxi and bus routes deviate from shortest distance routes in South African cities (Venter & Cross, 2011: 100). Competition between taxi associations means that routes sometimes end abruptly at the boundary of an association's service area, forcing passengers to transfer to another vehicle. Of course, passenger rail travel times and distances cannot be estimated from road data. All of these realities point to the necessity of using actual public transport spatial data when measuring actual accessibility of low-income communities.

A second common shortcoming is the failure to take travel costs explicitly into account when estimating travel impedance. Affordability of public transport fares is a very important constraint on the mobility of many low-income households in developing countries (Diaz Olvera, Plat & Pochet, 2008: 1-4; Venter, 2011: 121). The monetary cost of public transport is thus clearly an important dimension of accessibility. Recognising this, Bocarejo & Oviedo (2012: 145) combined travel time and cost into a generalised cost function of a gravity-type index. Applying the measure to Bogotá's (Colombia) TransMilenio Phase 3 BRT system, the authors found that accessibility losses from fare increases would be offset by increases in speed, thus showing how travel time and cost are traded off in users' perception of accessibility to job destinations.

The accessibility measure described in the following section attempts to respond to both of these two limitations.

3. ACCESS-ENVELOPES TECHNOLOGY AND METHODOLOGY

The access-envelope technology is a planning tool for measuring the impact of both transport and job/housing delivery on the location-specific affordability of job access, at a community level for poor households. It is able to present complex, multidimensional relationships in a simple, intuitive manner that may aid analysis and communication of results with non-technical audiences and decision-makers during strategic planning or project-development processes. Because it takes monetary costs as well as time and distance into account, the access-envelopes methodology appears highly suitable to address the current gap in objective measurement of the relative effectiveness of different urban travel modes (Schmidt, 2014).

3.1 Input data

The technique, dubbed Access Envelopes, makes use of the following input data to account explicitly for the key factors affecting the quality of access to employment from a particular settlement:

- Jobs: The spatial distribution of potential jobs (that match the typical resident's skills and education profile) in the area.
- Potential wage levels: The level of wages that are typically paid in various employment areas vary according to the type of industry. The attractiveness of a job in a particular location is dependent on this wage.
- Area-wide public transport coverage: The spatial envelope of locations that can be reached via public transport routes operated by rail, bus and taxi operators determine the accessibility of those jobs from a specific origin. Public transport network data is used to calculate travel times and costs between an origin and all potential job locations. Travel times are dependent on the speed of each mode.
- Walking times: Time spent walking to the first public transport vehicle and from the last vehicle to the destination can be a significant proportion of the total travel time, and affects accessibility. Walking times are estimated using shortest distance assignments to the public transport route.
- Public transport costs: Fares charged for public transport impact on the feasibility of travelling to a job. If transport is too costly (relative to the potential wage), a community's access to jobs decreases as its net earning potential is reduced.

3.2 Methodology

The methodology calculates, for a specific origin, an access value to each destination in the study area. The access value is named the Net Wage After Commute (NWAC). This can be interpreted as the potential wage earnable at a specific job

location MINUS the money needed to get from the home to the location. By subtracting commute cost, we approximate the 'actual potential take-home pay earnable at the location at the end of the day'. This makes the measure sensitive to the fares charged by public transport operators and to operational policies such as forced transfers between services (which usually require payment of a second fare).

NWAC values can be plotted for all destinations, thereby producing a visual representation that is easily interpreted and easily related to other spatial data such as job distributions or census data. The map represents, for a specific origin area, the access pattern enjoyed by residents of that origin area, as they search for, or engage in work in the surrounding economy.

Key to the measure is the manner in which travel-time impedance is treated. A gravity-type approach is adopted, in the sense that job destinations that are further away are less attractive. This is consistent with travel behaviour theory. However, the travel time is not transformed into a theoretical impedance factor using some arbitrary mathematical function (such as, for instance, the negative exponential function that is commonly used). Instead, travel-time impedance is accounted for in terms of its potential effect on net earnings. This approach draws on the travel behaviour literature, which indicates that people tend to have a travel-time budget, an aggregate amount of time that they spend travelling daily. This time budget tends to stay constant over time (Zahavi, 1974). People habitually plan for travel as one of the activities in their day. Research has shown that, over time, commuters who save travel time by, say, speed improvements to the transport network, tend to compensate by spending the 'saved time' on new trips, or by moving further away in order to keep the total daily travel time constant (e.g. Levinson & Kumar, 1994: 320).

It is thus assumed that commuters have a travel-time budget or 'reasonable travel time threshold' that they can absorb without cost consequences. Thus, all jobs closer (in terms of time) than this threshold are not penalised – their NWAC values are simply determined by wages and public transport fares. As soon as the travel time exceeds this threshold, however, travellers to such jobs would be forced to compensate in ways that might decrease their net wage, for instance:

- At the work end, by reducing the amount of hours worked, which reduces the daily wage earned, or
- At the home end, by carrying the costs of spending fewer hours at home, which might include the need to pay for additional childcare.

At present, a travel-time threshold of 1 hour per direction (2 hours of travel per day) is used, based on the analysis of the StepSA travel data. This is higher than typical work travel-time budgets found in developed countries (in the order of 30 minutes per direction), to reflect the historically restrictive housing policies in South Africa. Only jobs further than 60 minutes away by whatever the fastest combination of public transport modes is, incur additional costs that are reflected in a reduced net wage after commute.

This approach combines the strengths of both gravity-type and threshold-type approaches to access measurement. It takes the deterrent effect of long travel times into account, without requiring either an arbitrary deterrence function or an arbitrary 'hard' threshold to be specified.

Data is needed on actual taxi, bus, and rail services (including routes, fares, and travel times) in the entire study area, to a sufficiently high level of accuracy that walking distances to and from public transport routes can be estimated. This is probably the most demanding aspect of the access-envelope measure, as public transport data are typically not available or of poor quality. The authors depended on already available network data for bus and rail services, supplemented by additional data collection on taxi routes and fares in the case study areas below.

Apart from the NWAC map output, it is also possible to calculate several summary indicators to capture the overall performance of a settlement/transport combination under given circumstances. Two potential summary measures were explored to date, namely:

- The total number of job opportunities that can be reached with an NWAC value larger than R80. This reflects the size of the pool of jobs that can be reached, and still provides a retained income of R80 per day or more. The limit of R80 was selected as a reasonable minimum daily net wage; the higher this indicator, the more likely a job seeker would be to find a suitable job.
- The average NWAC value for the closest 200 000 jobs. This indicator reflects the distribution of wages and travel times and costs in the surrounding area, while controlling for the number of jobs. Cities with low wages or high transport costs would score lower on this measure.

The NWAC concept, while building on previous and current practice in accessibility measurement, offers a novel method of combining job income, travel time and travel cost into a single measure, and is, therefore, sensitive to both land-use and transport-delivery patterns. The NWAC measure is intuitive and easily interpretable, as is shown in the following case studies.

4. ILLUSTRATIVE CASE STUDIES OF ACCESS-ENVELOPE ANALYSIS

A number of case studies were developed to test and illustrate the access-envelope methodology for various indicative cases of public transport supply. The case studies are all concentrated within the City of Tshwane, as reasonably up-to-date GIS layers of bus and rail public transport networks were readily available. Manual data collection was undertaken to validate the networks, and to add further information on taxi service patterns and fare systems.

Data on potential wage income in all potential destination areas in Tshwane were obtained from the Gauteng transport model's updated job location data for 2011. These wage levels were correlated with the job types and wages reported by residents in the study areas during the StepSA surveys, to ensure that only potential jobs that corresponded to residents' education and experience levels were included in the analysis. Table 1 provides a summary of the access-envelope calculations for Figures 1-8.

Table 1: Summary statistics of access-envelope calculations

Origin area and scenario	Reference figures	Total job opportunities in NWAC larger than R80	Average NWAC value for closest 200k jobs
Soshanguve (as is)	Figures 1 and 2	657348	R 95.84
Soshanguve (under-employed scenario)	Figure 6	0	R 56.17
Mamelodi Central (walk feeder to PT*)	Figure 3	710530	R 107.70
Mamelodi East (local taxi feeder to PT*)	Figure 4	660268	R 102.80
Mamelodi East (BRT trunk and feeder scenario)	Figure 5	663939	R 106.03
Lotus Gardens (as is)	Figure 7	677752	R 110.89
Lotus Gardens (no rail access scenario)	Figure 8	582524	R 104.93

* Public transport (longer distance bus, rail and taxi routes)

4.1 Comparative analysis between two or more origin areas

Figures 1 and 2 show the NWAC and contour plots calculated with Soshanguve as origin. Soshanguve is conventionally considered a relatively poorly located former township area to the north of Pretoria. The NWAC surface indicates that work destinations clustered around Rosslyn, Pretoria North, Pretoria Central, and as far as the Silverton industrial areas and even parts of Centurion are accessible from Soshanguve within a relatively high NWAC value of R80 or more. The typical worker or work seeker in Soshanguve can access job opportunities within key clusters of employment in Tshwane and still take home at least R100 in earnings per day, after paying for his/her commute. This is driven, to a large extent, by the fact that Soshanguve is connected by a passenger rail service to the major employment areas, providing low-cost and relatively speedy transport to the rest of the city.

Nevertheless, when superimposing the NWAC contours on the actual distribution of jobs in Tshwane (Figure 2), it is clear that, while the majority of jobs are within the R80 NWAC envelope, they are relatively distant. Thus, the average earning potential relative to the closest 200 000 jobs is only R95 per day, as shown in Table 1.

Figure 3 shows the NWAC surface for residents in the old, central part of Mamelodi, for reasons of comparison. This part of Mamelodi is located close to rail, bus and taxi facilities. Large parts of the Pretoria economic core are accessible with very low travel time or travel cost penalties. Comparing Figure 3 to Figure 1 shows that Mamelodi is a superior location to Soshanguve in terms of jobs access. This is also reflected by the higher number of jobs that can be accessed from Mamelodi than from Soshanguve within a NWAC=R80 contour (Table 1). This case thus illustrates the use of the NWAC methodology for comparative analysis between two or more housing areas to determine what the likely access advantages of one over the other might be, taking actual travel supply and distributions of employment opportunities into account.

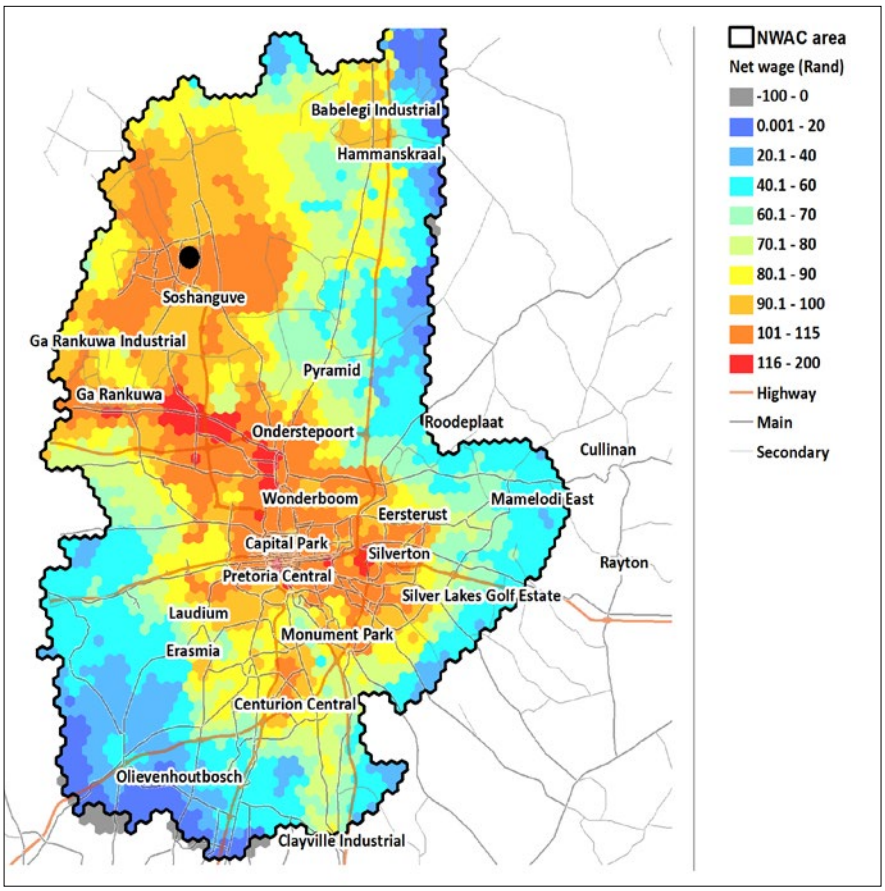

Figure 1: Soshanguve net wage surface

Source: Authors' calculations

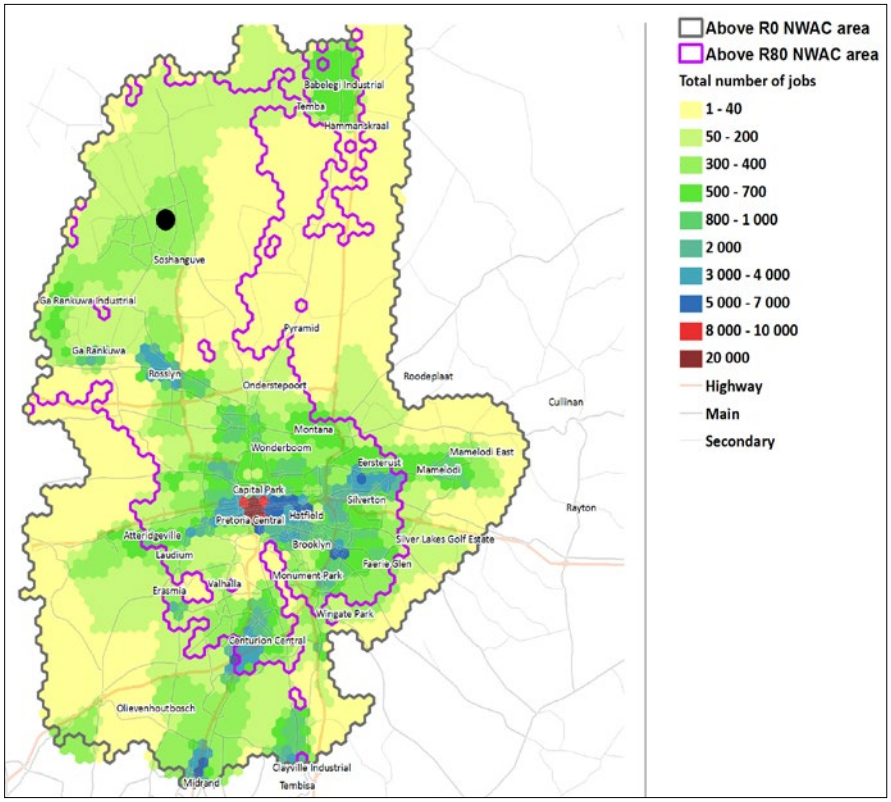

Figure 2: Soshanguve net wage contours superimposed on total jobs

Source: Authors' calculations (Job data obtained from Gauteng Transport Study 2011)

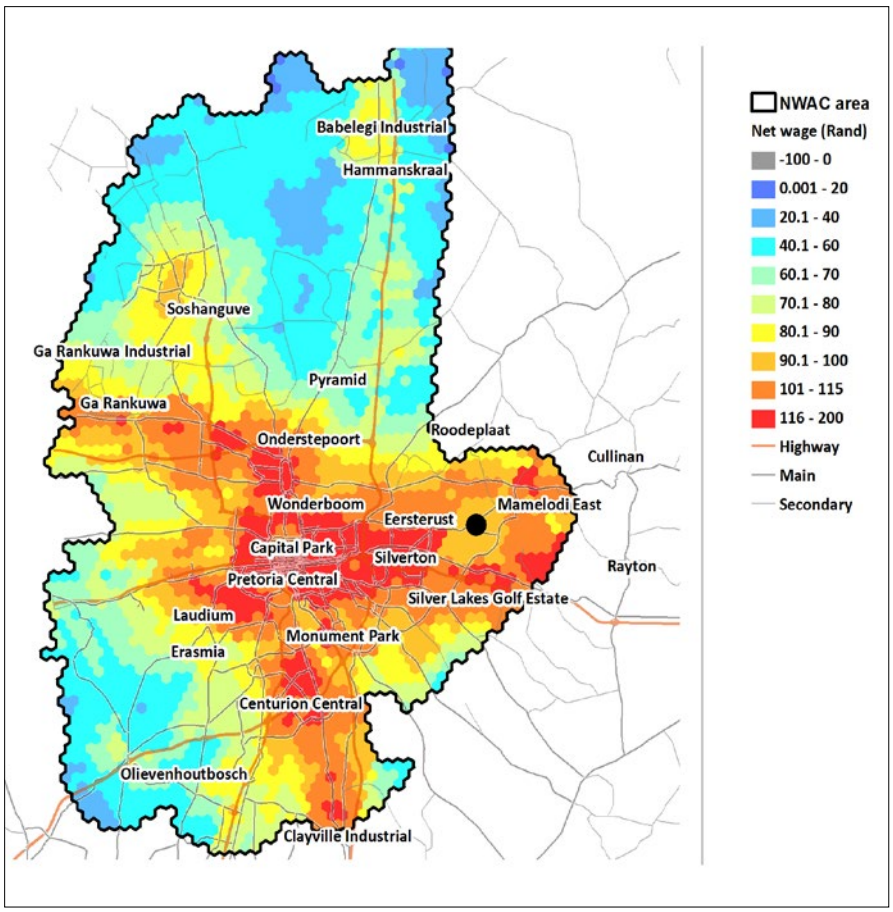

Figure 3: Mamelodi Central (walk feeder to public transport) net wage surface

Source: Authors' calculations

4.2 Impact of local access to public transport

The time and money needed to get from the home to the first public transport vehicle could be a significant component of the commute, both in terms of time and money (Venter & Cross, 2011: 102-103). In order to examine the impact this factor has on accessibility levels, the access envelopes were compared for two origin areas that are identically located relative to the larger space economy, but with different local access patterns.

Mamelodi East consists mainly of informal settlements located on the periphery of Mamelodi. Distances to bus termini, rail stations and taxi stops are relatively long, requiring commuters to undertake long and time-consuming walk trips to public transport, or alternatively to take a local trip as a feeder to the rest of the public transport system. The local taxi charges an additional fare of R6 just to get to the rail or bus station in Mamelodi.

To examine the effect of this additional feeder trip component on access patterns, Figure 4 can be compared to Figure 3 (which required no such long feeder trips). The difference is marked: the need to take an extra feeder trip constrains the NWAC surface considerably, in effect reducing workers' options for retaining larger parts of their incomes. Table 1 indicates that the need to pay for a feeder taxi trip reduces the number of job opportunities that can secure a retained income of R80 per day or more, by up to 50 000.

4.3 Examining the impact of a Bus Rapid Transit intervention

Figure 5 illustrates the application of the access-envelope methodology for testing the access benefit of hypothetical transport interventions. The City of Tshwane is implementing a BRT network that will produce fast service (due to the use of dedicated bus lanes and integrated lines) and lower costs, especially for trips requiring transfers from feeder services, as feeder bus services are also to be subsidized (in contrast

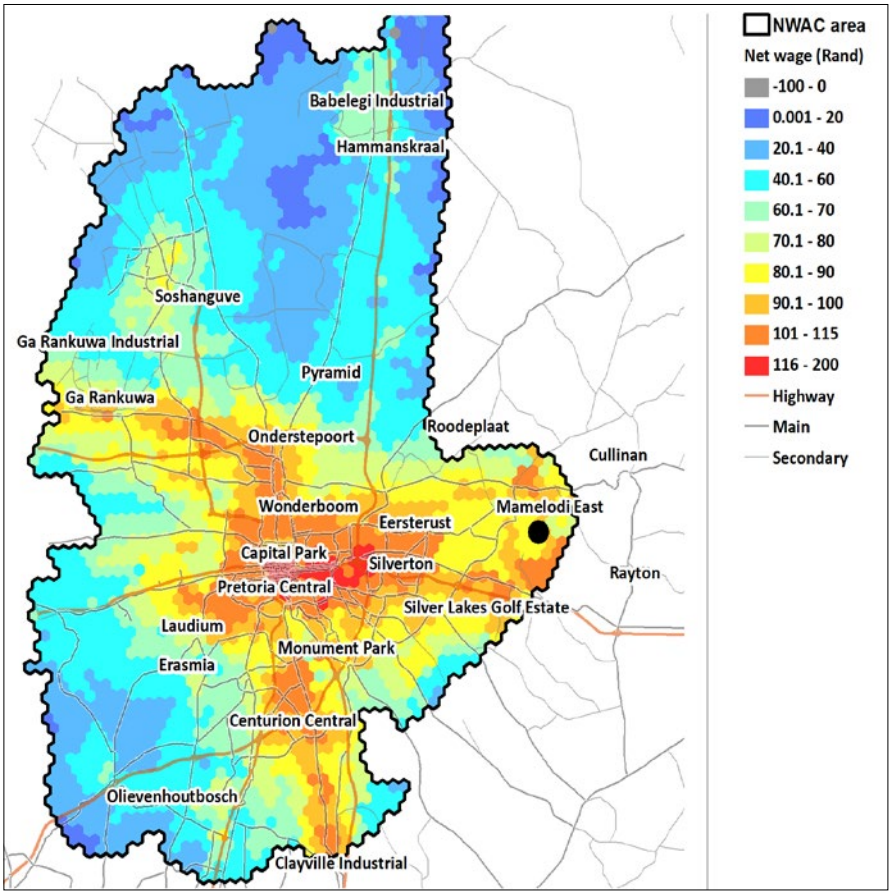

Figure 4: Mamelodi East (taxi feeder to public transport) net wage surface
Source: Authors' calculations

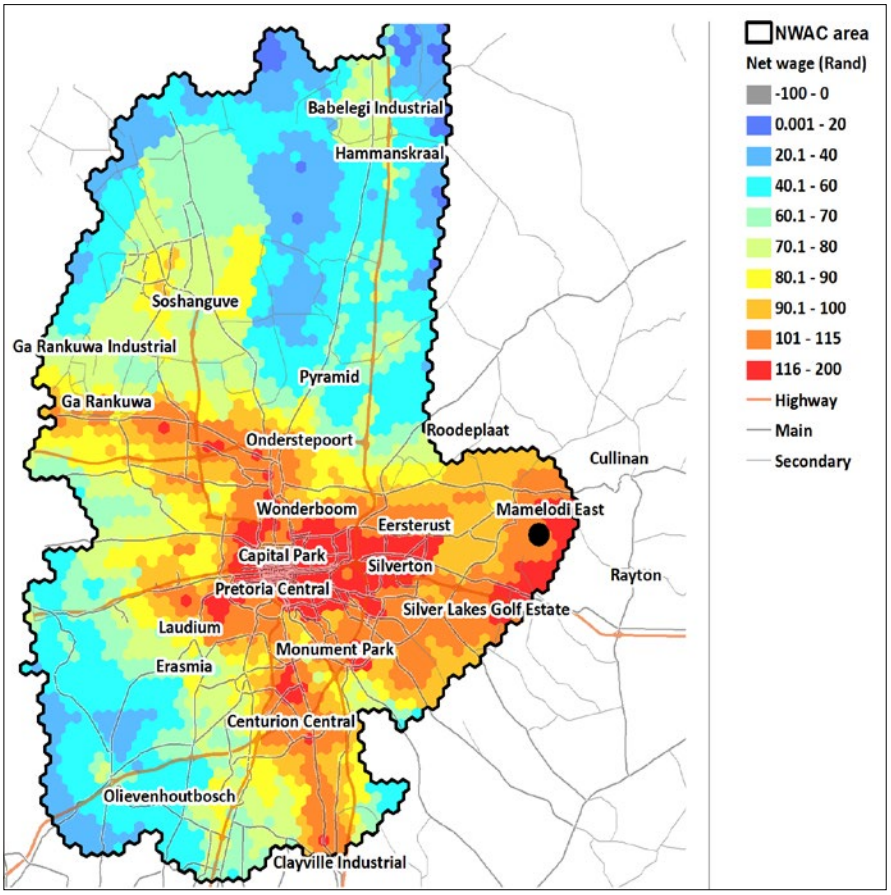

Figure 5: Mamelodi East (BRT feeder and trunk) net wage surface
Source: Authors' calculations

to the existing practice with taxi feeders). Although the first routes are rather modest in scope, the Phase 1 network will eventually connect Pretoria Central with Kopanong/ Rosslyn in the North, Menlyn in the East, and Mamelodi. The scenario tested, in this instance, is for the complete first phase, assuming a dedicated bus route is operated from Mamelodi via Pretoria East to the CBD. Typical bus travel speeds and fares were assumed for the sake of the illustration.

The results (comparing Figures 5 (with BRT) with Figures 3 and 4) show the likely benefits to be quite modest. Access to potential job opportunities in Pretoria East is expanded as a direct result of the routing of the BRT line from Mamelodi through the New East. But access to the main employment areas in the Pretoria CBD and its industrial zones remains unaffected by the BRT. The main reason for this is the fact that the BRT route duplicates the existing rail service between Mamelodi and the CBD, without offering substantial improvements in speed or cost over rail to these (more distant) destinations. The main beneficiaries of the BRT are likely to be residents of Mamelodi East, who currently enjoy poor within-settlement access to public transport – their net wage would increase by about R3 per day, on average (Table 1). It is further clear that the full access benefits of the BRT investment can only be maximised if new employment opportunities are concentrated along the portions of the route with enhanced accessibility – notably the outer sections of the route between Mamelodi and Menlyn, which are the sections without current rail access. A coordinated spatial and transport strategy should target these areas for investment.

4.4 Impact of underemployment on net wage

To illustrate how the access-envelope methodology can be linked to the employment conditions of specific subsectors of the population, a stylized scenario was developed for underemployed working residents of

Soshanguve. It was assumed that workers access part-time or 'piece-job' work that enables them to work three days a week, but that they still travel to potential job destinations on the other two days a week to seek work. This effectively reduces their average daily wage by 40% without reducing their commute costs.

The impacts of such underemployment are shown to be very severe. Comparing Figure 6 with Figure 1 shows that the number of jobs effectively available for an average retained income of R80 per day or more shrinks drastically, and that large parts of the job-rich CBD surrounding areas are now excluded from this contour. Figure 6 shows that it becomes impossible to obtain an average income of higher than R70 per day.

4.5 Importance of rail service to job access

This illustrative case set out to assess the importance of rail – with its relatively high speed and, especially, its low fare – on the NWAC surface. The origin area of Lotus Gardens towards the West of Pretoria was chosen, as this represents a relatively well-located lower middle-income area with good access to rail and other public transport services.

Figure 7 confirms this positive picture for the status quo. Of all the scenarios considered, Lotus Gardens residents enjoy the highest average net wage (NWAC) value for the closest 200 000 jobs, at R110. Removing the rail option from the picture produces Figure 8. Access to jobs located close to the main East-West axis – including Pretoria West, the CBD, and Hatfield – as well as the core of Centurion remains relatively high, as these areas are well-served by bus and taxi modes. However, the NWAC values for most other parts of the city decline, even for destinations further away from the rail line, thus requiring another feeder trip for the last mile. This confirms that rail plays an important role in providing affordable job access even to areas not adjacent to the rail line.

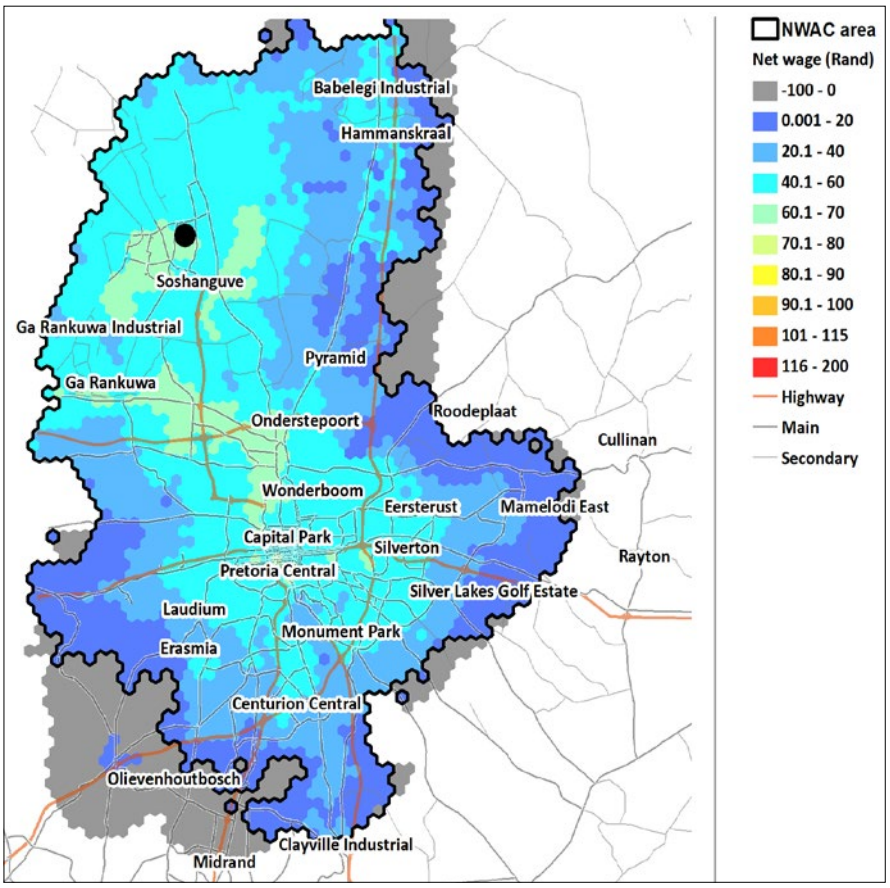

Figure 6: Soshanguve underemployed population: net wage surface
Source: Authors' calculations

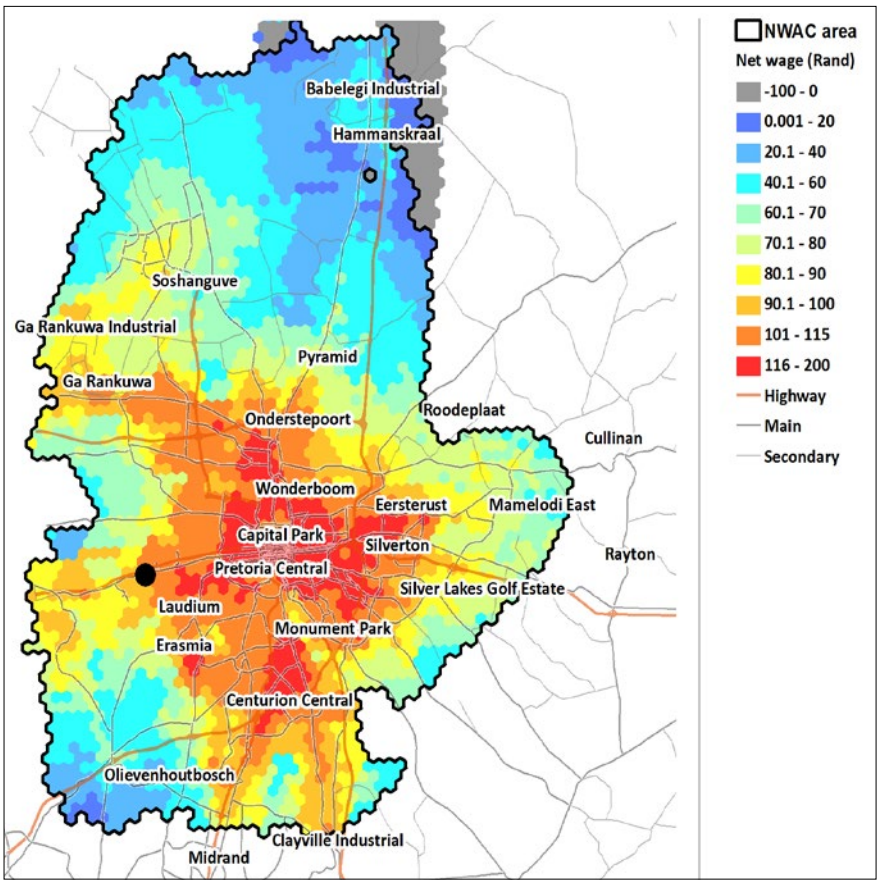

Figure 7: Lotus Gardens net wage surface
Source: Authors' calculations

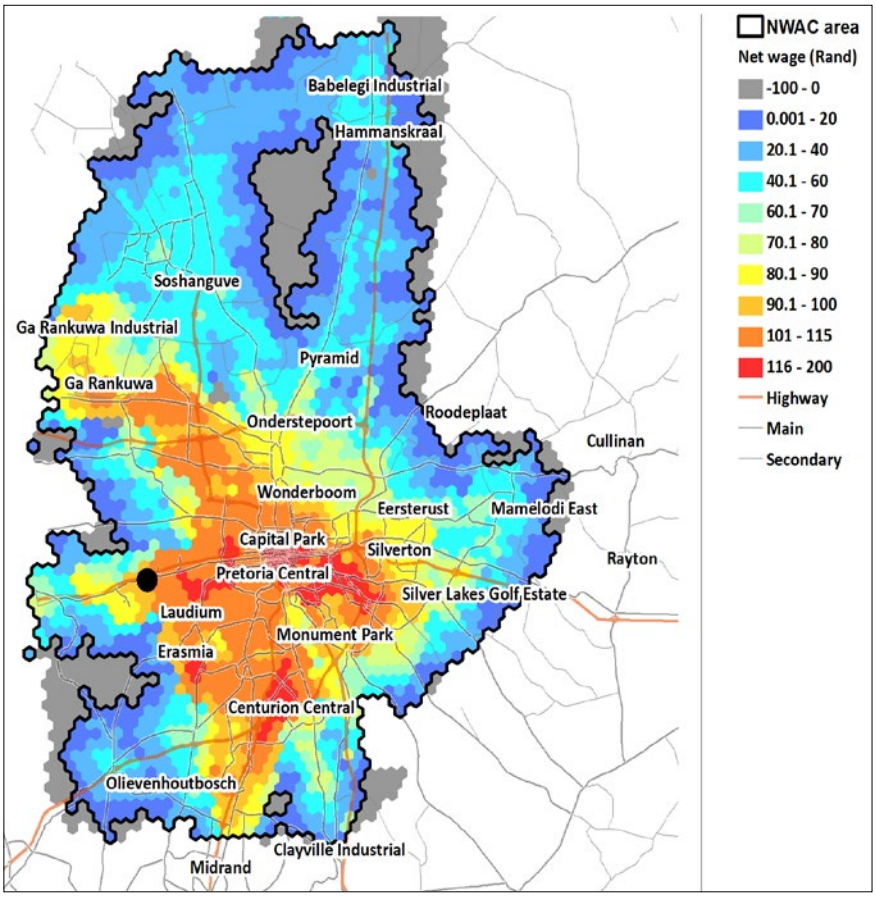

Figure 8: Lotus Gardens without train scenario: Net wage surface

Source: Authors' calculations

5. CONCLUSIONS

The article described the development of a GIS-based technique capable of presenting complex, multidimensional spatial relationships in a simple, intuitive manner suited to the analysis of housing, spatial development and transport interventions or strategies during strategic planning or policy development processes. The access-envelope methodology offers improvements over existing accessibility measures by explicitly accounting for public transport service patterns; including transport fares as a dimension of accessibility, and deriving a single intuitive measure of access reflecting the potential income earnable by a person living in a certain location, after paying for transport.

Using generally available data on job opportunities and public transport services in the City of Tshwane, the application of the methodology to a variety of typical planning questions was illustrated. A limitation of the method is its reliance on accurate spatial data on public transport routes and fares. Unfortunately, municipalities rarely keep such data updated. It is strongly recommended that municipalities keep improved records of public transport supply for these purposes. The present shift to transit-oriented development, and the concomitant questions regarding the effectiveness of BRT against other modes, highlight the need for accurate public transport data, at local municipal level, in order to make precise and valid comparisons relative to livelihoods and labour market access.

Because it takes monetary costs as well as time and distance into account, the access-envelopes methodology could assist in assessing different interventions affecting the success of poor households in the urban labour market at different spatial points. Significant results to date point to the importance of planning for mixed modes which include rail planned together with other forms of public transport, and the critical importance of measures to reduce the cost of the 'last-mile' connection, whereby residents of poor settlements reach their public transport access point.

The case studies highlighted the importance of the patterns of local access within a settlement. Being located within walking distance of bus and rail services significantly reduces travel cost and enhances accessibility and earning potential. Implications for settlement planning include, first, that locations close to intermodal transport facilities should be prioritised for low-income housing development. Secondly, more emphasis should be placed on reducing the cost of local taxi services within townships. One option is to incorporate feeder taxis into larger systems such as BRT systems, allowing authorities to regulate and/or subsidise feeder trip fares.

Access envelopes need to be further developed to increase their usefulness as a planning tool. Further work is required to add settlement scenarios (e.g. different housing locations and densities) and economic development scenarios (e.g. different job-creation strategies), to test the ability of the tool to meaningfully evaluate different integrated spatial and transport development approaches. The results also need to be compared with actual employment and livelihoods outcomes to verify the validity of the NWAC metric as a meaningful way of measuring opportunity.

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