Using a Joint Destination-Mode Choice Model for Developping Accessibility Measures

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Abstract

Evaluating the need for changes in the transport system, and forecasting or evaluating the impact of those changes, is no trivial task. Accessibility measures (Hansen, 1959) are a tool that can help to fulfill this task. Very different measures were proposed in the litterature under this name (Geurs and van Wee, 2004). What they have in common is that they evaluate the transport system not only based on travel costs, but on the activity opportunities it allows to reach.

Choice models derive choice probabilities from a postulated random *utility* decision makers get from their chosen alternative (Ben-Akiva and Lerman, 1985). It is rather natural to interpret this utility value as individual satisfaction, and thus to use the *expected maximum utility* from a destination choice model in a transport system as an accessibility measure for this transport system (see *e.g.* Niemeier, 1997).

This paper will report on the development of an accessibility measure based on a joint destination-mode choice model. This has several advantages over more simple measures: all modes being considered concurrently, the impact of the availability of various modes on the global accessibility can be assessed; being based on individual choices, individual characteristics, such as socio-demographics or individual vehicle accessibilities, can be part of the measure.

The development of the model is part of the European-African "MAXess" project. Models are being estimated on the Swiss National Travel Survey, and a travel survey in the Cape Town area, South Africa. Accessibility measures for the two areas will be presented, emphasizing effects elicited by the measure.

1 Introduction

Evaluating the need for changes in the transport system, and forecasting or evaluating the impact of those changes, is no trivial task. Accessibility measures (Hansen, 1959) are a tool that can help to fulfill this task. Very different measures were proposed in the literature under this name (Geurs and van Wee, 2004). What they have in common is that they evaluate the transport system not only based on travel costs, but on the activity opportunities it allows to reach.

Geurs and van Wee (2004) mention four "components" that an accessibility measure might contain, explicitly or implicitly: (a) the *land use* component, that is, the spatial distribution of activity locations (supply) and home locations (demand); (b) the *transport component*, representing the cost of accessing an activity location; (c) the *temporal component*, representing potential temporal constraints; and (d) the *individual component*, representing individual differences in needs, preferences and abilities. Depending on the aim and available data, an accessibility measure might put more emphasis on one or the other component.

In most, if not all, urban areas, a certain level of segregation is observable: neighborhoods tend to be relatively uniform in the characteristics of the individuals that live in them. This can come from a variety of reasons: price, willingness to live with peers, or even political constraint. If pronounced, this segregation might have to be taken into account when looking at accessibility: what good would more road infrastructure do to individuals who do not have the means to own a car? This remark helps to see the importance of the *individual component* of accessibility.

Joubert et al. (2015) compared two approaches to study accessibility in segregated contexts. The first one is an ad-hoc household accessibility measure, based on expert knowledge and manual calibration. The second one is a much more light-weight measure in terms of data input, that just requires information available from the OpenStreetMap open database, and is purely geographic. Even though the simple measure already helps identify low-accessibility townships, only the level of detail provided by the household based measures help differentiate between a township close to work opportunities and a very isolated one. However, the manual design of arbitrary weights for numerous components of the accessibility is difficult to justify, and the sensibility of the measure to this specification is not clear.

A popular way to include this individual component in accessibility measures comes from discrete choice modeling. Choice models derive choice probabilities from a postulated random *utility* decision makers get from their chosen alternative (Ben-Akiva and Lerman, 1985). It is rather natural to interpret this utility value as individual satisfaction, and thus to use the *expected maximum utility* from a destination choice model in a transport system as an accessibility measure for this transport system (see *e.g.* Niemeier, 1997). In particular, if the choice model contains a cost component, it becomes possible to express the accessibility in monetary terms and use it in economic analyses, for instance of consumer surplus (Neuburger, 1971; Leonardi, 1978).

This paper will report on the development of an accessibility measure based on a joint destination-mode choice model. This has several advantages over more simple measures: all modes being considered concurrently, the impact of the availability of various modes on the global accessibility can be assessed; being based on individual choices, individual characteristics, such as socio-demographics or individual vehicle accessibilities, can be part of the measure.

The development of the model is part of the European-African “MAXess” project. Models are being estimated on the Swiss National Travel Survey, and a travel survey in the Cape Town area, South Africa. Accessibility measures for the two areas will be presented, emphasizing effects elicited by the measure.

2 Method

Discrete choice models allow to model travel behavior taking into account personal characteristics and attributes of the transport system. Interpreting the utility as individual satisfaction, the expected maximum utility for a given person, given a certain state of the transport system, can be used as an accessibility measure.

Though this fact is recognized since long, using such measures for general appraisal of the transport system is surprisingly not common. The potential of such a measure are:

- To take into account the sociodemographics of the population in the measure. A car-oriented measure might for instance fail to recognize the full lack of accessibility of a South-African Township with very low car availability.

- To consider several modes in the same measures, with weights coming from the observed behavior. For instance, the high congestion in a densely urbanized area might be more than compensated by an attractive public transport system. In terms of transportation policy, this would mean not investing too much in car accessibility if most of the needs can already be fulfilled by public transport, for instance.

- To evaluate the advantage of vehicle ownership, by comparing accessibility for all modes but car and all modes with car.

As the basis for such a measure, one needs a model that includes:

- Destination choice (the necessary component for an accessibility measure)
- Mode choice (to be able to create a multiple-modes measure)
- Socio-demographic characteristics

That is, a joint destination-mode choice model. After testing different specifications, a nested logit with one nest per mode was retained as the best formulation. The nested logit formulation allows for a two-level modeling, where the choice of the mode might have high variance, but the choice of the destination given the mode be highly dependent on distance, or the opposite.

The usage of a choice model allows to easily include vehicle availability and socio-demographics in the measure itself. The measure can then be displayed on a map, considering the average accessibility in different areas given the socio-demographics of the population, or analyzed on an individual level.

In assessing the impact of transport infrastructure, it is usual to think in terms of impact on geographical regions, rather than on each individual in the population. To produce maps from the measure, the following is done:

1. A population, from the census or a synthetic population, is used as the basis for computation
2. For each individual, the expected maximum utility for the kind of decisions at hand is computed
3. aggregate per cell is computed and displayed on the map

Those aggregated values can be average, or more elaborate (for instance an analogous of the Gini coefficient to represent local disparities).

2.1 Obstacles for a Multimodal Measure in a Segregated Context

As stated in Section 1, one of the reasons behind using an accessibility measure based on a joint mode-destination choice model is to be able to look at the effect of transport policies on lowering the isolation of segregated neighborhoods.

The South-African context is in this regard a textbook example, with lasting consequences of the segregationist Apartheid Regime. In fact, segregation is so strong it creates modeling difficulties:

- Inhabitants of the Townships rely strongly on para-transit for mid-distance transportation, but organisation of those service is opaque;
- In addition, unemployment is still pervasive in those neighborhood, and
- Those persons are in addition too poor to possess a car.

For those reasons, the following happens in the Cape Town Survey:

- though inhabitants of townships answered the survey, the vast majority did not report any trip, let alone *work* trips
- as a result, no shared-taxi trip at all was reported for work purpose.

This forces to let the important taxi services outside of the measure, and rely on behavioral parameters coming from other segments of the population to value accessibility. This is a problem, but not dramatic: the most important factor in accessibility difference given a location — car ownership — is known from the data.

2.2 Data and Generation of the Choice Set

For Switzerland, the choice data comes from the National Travel Survey 2010. For South Africa, the choice data comes from an household travel survey in Cape Town. To estimate choice models, the observed choice from the survey is complemented by a generated choice set. This choice set is generated as follows:

- given the origin of the previous trip and the destination of the trips next to the activity, activity locations are picked at random in a "prism" containing all of the area accessible by traveling a total of less than 80 km (which is above the 95% quantile of the observed choice) For Switzerland, locations come from the Enterprise Census.For Cape Town, facilities are generated on a 500m resolution grid on all areas categorized as built in the ESA land cover dataset (European Space Agency, 2016).

- for each destination, travel time and cost are computed for each mode. Travel times are computed using the MATSim infrastructure (MATSim, 2016). Travel costs for Switzerland are based on average kilometric fuel price for automobile and on the price tables from the national rail operator for public transport .

3 Results

Results presented here are for a model of leisure mode/destination choice for Switzerland. Results for Work purpose, comparing Switzerland and Cape Town, are being finalized, and will be included in a revised version of the paper.

Parameters for the Switzerland leisure model are presented in Table 1. The model is kept simple, and contains alternative specific constants, parameters for the logarithm of the travel time (the β_{mode} parameters), as well as additional parameters for the log of travel time for public transport in case the person owns an unlimited transport ticket (GA), a half-fare ticket (HT) or a local ticket (LOCAL), and a dummy for the mode bike in case the person has a driving license, based on the assumption that bike enthusiasts are less likely to posses a driving license, and that some bike users might have preferred car if they could. The model was built incrementally from a simple MNL formulation using only linear travel times, and only those additional transformations or parameters that lead to significant improvements in the likelihood were retained. In particular, no formulation could be found that included price in a meaningful way. This might be due to the revealed preference kind of data, where cost and travel time are highly correlated.

The results of this model are no real surprise, and their main purpose is to be used to study accessibility.

Using this model, several measures are designed. Each of those measures is computed for each individual in the national travel survey, and then the valued are averaged of all individuals with residence in the same cell. Unless otherwise specified, maps use a quantile coloring, where

Table 1: Parameters from the Model

Description	Coeff. estimate	Robust Asympt. std. error	t-stat	p-value
ASC_{bike}	1.85	0.683	2.70	0.01
ASC_{pt}	0.0644	0.695	0.09	0.93
ASC_{walk}	6.86	0.462	14.86	0.00
β_{GA}	0.158	0.0320	4.93	0.00
β_{HT}	0.0653	0.0258	2.53	0.01
$\beta_{LICENSE\_BIKE}$	-0.614	0.361	-1.70	0.09
β_{LOCAL}	0.169	0.0302	5.58	0.00
β_{bike}	-0.235	0.205	-1.15	0.25
β_{car}	-0.276	0.0355	-7.76	0.00
β_{pt}	-0.508	0.0822	-6.18	0.00
β_{walk}	-0.917	0.103	-8.93	0.00
μ_{bike}	6.40	6.01	0.90[1]	0.37
μ_{pt}	1.00	1.73e-09	1.06[1]	0.29
μ_{walk}	1.74	0.221	3.34[1]	0.00

Summary statistics

Number of observations = 943

$\mathcal{L}(0) = -6099.256$

$\mathcal{L}(\hat{\beta}) = -4877.120$

$\rho^2 = 0.200$

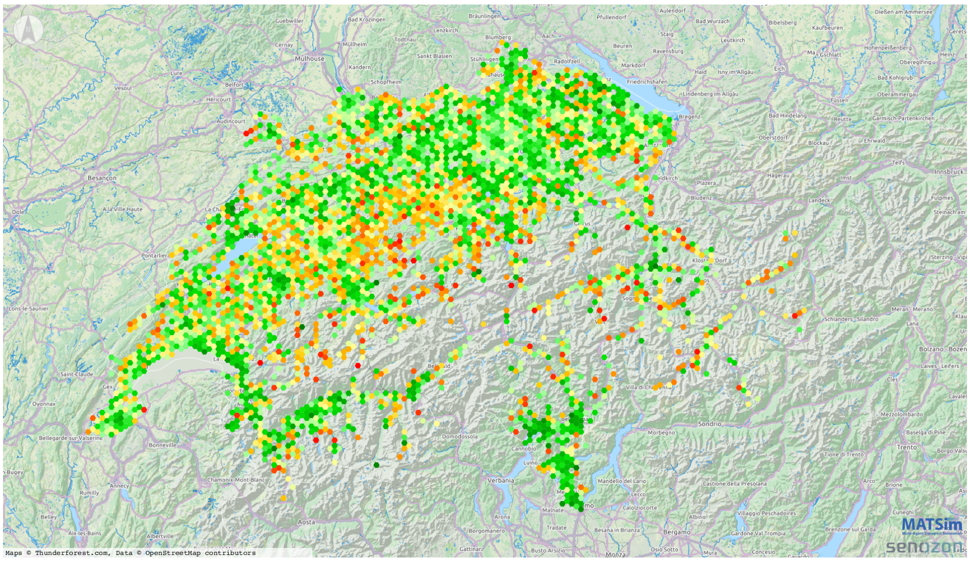
$\bar{\rho}^2 = 0.198$

values below the median go from red to yellow, and values above the median go from yellow to dark green.

The first one is the basic accessibility measure: just the expected maximum utility from the choice model taking into account car availability, presented in Fig. 1. It shows a rather uniform picture, with only some parts close to the Alps displaying low accessibility.

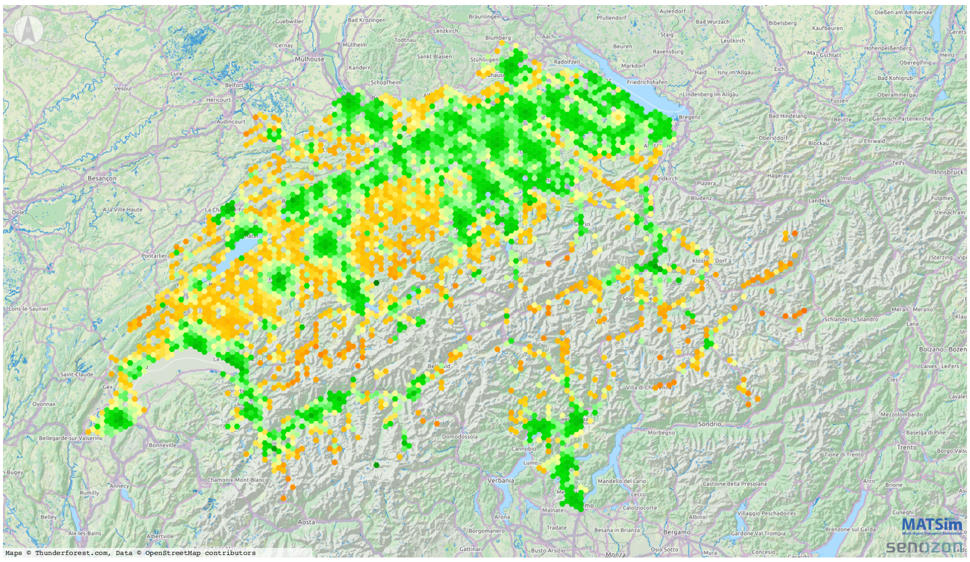
The second one, on Fig. 2 only ignores car availability: individuals are assumed to all have access to a car (and to be able to drive it). Here the picture shows much greater contrast, with rural areas having clearly less accessibility than urban areas. What this seems to indicate is that

Figure 1: Basic accessibility (quantile colors)



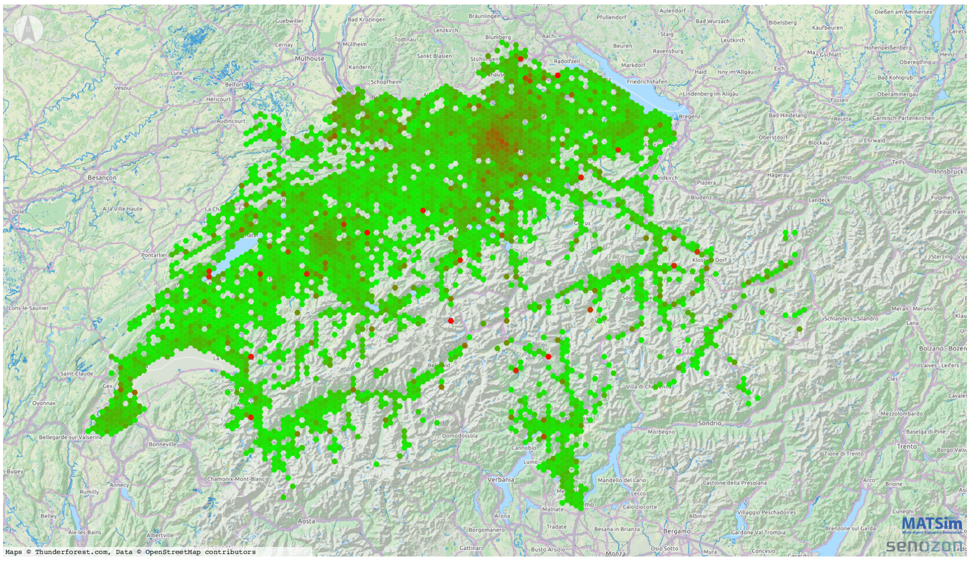
automobile ownership tends to level out the accessibility landscape; in another sense, individuals tend to acquire a car in answer to a lack of accessibility, and individuals with better non-car accessibility (because of density or good public transport) do not consider the cost of getting and maintaining a car worth the limited change.

Figure 2: All modes accessibility (quantile colors)



Finally, Fig. 3 shows the “advantage” of public transport, in the sense of the increase of accessibility occurring by making public transport available. It ranges from green (low) to red (high). Here, Zurich, and, in a lower extent, Basel and Bern show up in red, indicating that the good public transport service of those cities seem to give better accessibility than car itself.

Figure 3: Public transport accessibility advantage



4 Conclusions

This paper presents the development of an accessibility measure aimed at taking into account all modes available jointly, as well as individual characteristics, while remaining relatively parsimonious on data. This is part of a joint European-African effort, aiming at developing ways to evaluate transport policies in the African context, with relatively low data availability and high spatial segregation.

The application of the measure to Switzerland shows its ability to reveal some interesting effects, such as the natural leveling of accessibility by vehicle ownership, in this land where virtually every citizen can afford a car if needed. The application to South Africa, still in progress, might show a totally different picture: there, seeing people walk long distance along highways is by no means an unusual sight.

Hopefully, such measures might help identifying the most urgent problems, and evaluate the viability of various policies to partially solve those issues.

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