WALKYOURPLACE - DEVELOPMENT OF A WEB-BASED TOOL TO EVALUATE URBAN ACCESSIBLITY

Stefan Steiniger, Pontificia Universidad Católica de Chile ssteiniger@uc.cl
M. Ebrahim Poorazizi, University of Calgary, mepooraz@ucalgary.ca
Andrew J.S. Hunter, University of Calgary, ahunter@ucalgary.ca

ABSTRACT

We present a web-based tool for the assessment of urban accessibility that focuses on the citizen as user. If the user provides a location and the time that they are willing to travel, then the WalkYourPlace system will evaluate in real-time the extent of the area that is accessible. This area is then analyzed using "quality of life" indicators, such as the number of grocery stores, shopping and recreation facilities, past occurrence of crime, etc., to calculate an accessibility score. When transit data are available, users can evaluate combinations of travel modes, such as walking with transit use.

Keywords: walkability, accessibility, urban planning, web platform

1. MOTIVATION

In cities demand for housing varies with the neighborhoods. Thereby those neighborhoods that show a higher demand generally attract higher purchase prices. A higher demand can be associated with perceived quality of life (Adams and Tiesdell, 2013; Barton et al, 2010), housing styles (i.e. house or apartment, new or old, big or small, etc.), and the characteristics of a particular location, for instance its accessibility to mayor workplace centers in a city. Studies such as the National Association of Realtors (NAR, 2011) and newspaper and blog discussions (e.g., Harris, 2012; Palmer, 2012) show that walkable access to daily services is perceived by citizens to be important. Thereby a neighborhood is considered "walkable" if services for daily and weekly routines, such as bringing kids to school, grocery shopping, banking services (e.g. an ATM), as well as sports and entertainment locations (e.g. cafe, bar, cinema) can easily and safely be walked to in 5 to 15 minutes (Moudon et al. 2006). "Walkability" can be seen as a particular form of "accessibility", with the latter described first by Hansen (1959). Whereas walkability has a strong local or neighbourhood focus, accessibility accounts for access to economic activities (e.g., work places) and opportunities (e.g., leisure) on all geographic scales, from the neighbourhood to city to region.

Evaluation of urban accessibility is not only of interest to citizens but also a subject of transportation planning. Developing tools for the evaluation of accessibility and integrating accessibility evaluation in land-use planning has recently been highlighted as one of the research and policy recommendations of the International Conference on Competition and Ownership in Land Passenger Transport (THREDBO) - Workshop 6 in 2012 (Stanley and Lucas, 2013). Indeed, French, as a well as British planning guidelines already recommend the evaluation of accessibility when (larger) transport infrastructure projects, such as a new urban light rail, a new regional train connection, or a new highway, etc., are proposed (DfT, 2007; Crozet and Villalba 2013).

Several expert software systems exist that allow evaluation of accessibility. Among them are MOSART (Crozet et al, 2012) and SNAMUTS (Curtis and Scheurer, 2010). MOSART has a focus on measuring accessibility to workplaces and looks at zones larger than a street block (i.e. a 250m grid). Due to its data needs it has only been used for accessibility evaluations in Lyon, France, and is (currently) not accessible online. SNAMUTS, an Australian tool, has a focus on measuring and comparing access by car and public transit, and represents more a methodology than an existing "ready–to-use" software. Both systems are at the moment neither available to experts in municipal and governmental planning and transportation agencies, nor to the public, so that these tools can be used in the public consultation and participation processes (Drummond and French 2008, Hunter et al. 2012)

However, there exist several fairly user-friendly web-based tools for measuring walkability, such as walkscore.com and walkonomics.com. But these systems usually focus on a single travel mode, i.e. walking, whereas we believe it is important to evaluate accessibility for different travel modes, including mode combinations. Walkscore.com offers a "BikeScore" since 2014, and has options to evaluate Transit opportunities for US and Canadian Cities since 2014.

In summary appreciation and evaluation of urban accessibility is done by citizens, urban planners, health professionals and social science researchers. But existing tools are difficult to access or have short-comings with respect to options for the evaluation of other modes than walking or multi-modal trips. For these reasons we developed an online tool for citizens and planners that allows evaluation of accessibility to city services, parks, shops, etc. - which we called “WalkYourPlace” (Steiniger et al, 2013). A particular application focus for the web-based tool is its use in support of planning related public participation activities – and as part of general public participation platform, called PlanYourPlace. As it would be useful to use the same tool in a batch-mode to evaluate larger point datasets, i.e. to evaluate cities, we also strived to develop the tool in such a way that it can be used in form of a general web-service without a end user interface for citizens. Aside from developing the online tool we also aim to test and improve existing walk, bike and transit access calculation methods, since, as the literature shows, there are a multitude of options to measure accessibility (see for example, Talen and Anselin, 1998; Manaugh and El-Geneidy, 2011; Duncan et al, 2013).

2. TOOL REQUIREMENTS

For the design of the tool and its underlying architecture we need to consider: (i) the user group; (ii) the activities that the user should be able to perform (i.e. the tool’s functionality); and (iii) the context of use, such as the environment within which it will be used (Rubin and Chisnell, 2008). Within the PlanYourPlace project, the user group has been defined as community members that are interested in community planning and citizens interested in finding a new home. However, users also include municipal planners and officials, real estate agents, and developers. This means that we have to consider a wide range of demographic groups spread over different age groups, different computer skill levels, and groups with different degrees of knowledge in planning. Based on these conditions initial requirements of the tool are: (1) it must be easy to use; and (2) results need to be understandable to the layperson. Furthermore, the tool should be available at any time and ideally be used from any place. Therefore further requirements include (3): the tool is best provided via the Internet; and (4) the tool should be accessed via a web browser (i.e. not for download).

The requirements that can be derived from a user’s likely activities are function that permit to (5) calculate the accessible area or neighborhood for a specific location (and time) provided by the user; and (6) calculate an accessibility score based on attractors (services), detractors (e.g., crime), and / or amenities within the neighborhood. Thereby (7) the accessibility area and score should be calculated for a range of travel modes, such as walking, transit, and cycling; and (8) the extent of an accessibility area should depend on the time that a user would like to walk, bike, or use transit. We also define that travel distances calculated have to account for the real world urban infrastructure, including topological constraints such as a river.

3. ACCESSIBILITY EVALUATION AS WEB-PROCESSING-SERVICE

3.1. Accessibility Score Calculation

Several types of accessibility measures have been developed in the past due to different objectives in practical applications and different perspectives of disciplines such as planning, geography, economics, transportation, etc. Whereas Tillema et al. (2011) distinguish only broadly between two classes of measures, i.e. geographical accessibility measures and economical evaluation measures, Curtis and Scheurer (2010) elaborate 7 categories of measures, such as spatial separation measures, contour measures, utility measures etc. An overview of different measures is given in the works by Kwan (1998), Talen and Anselin (1998), Bhat et al. (2000), Geurs and van Wee (2004), Curtis and Scheurer (2010).

An example for a particular contour-based accessibility measure is “WalkScore ®” (WalkScore, 2011): Given a position the WalkScore method counts and weighs all the attractions, e.g. schools, services, shops, banks, coffee places, theatres, etc., in the area that can be reached within a certain walking time. We note that in the original walkscore.com implementation (“Street Smart”), the walking time was assumed (i.e. fixed) to be around 20 minutes, resulting in a circular area with a 1-mile radius (1609m). The WalkScore method returns a “walk” score that can be between 0 (not walkable) and 100 (very walkable). Notably the original walkscore calculation used a 1-mile circle and therefore an “as-the-crow-flies” approach to city travel. As such approach neglects topographic barriers, e.g. a river running through a city, or a highway dividing neighborhoods, our implementation had to replace this rough estimate by a better travel area estimate that was calculated based on the evaluation of the existing street and path network. Apart from this replacement, we adopted the basic method developed by WalkScore, resulting in three basic steps:

(1) calculation of an accessibility area, i.e. a walkshed, a bike-shed or transit-shed,
(2) retrieval of attractors (e.g. point of interests, POI) and detractors within that area, and
(3) calculation of an access score, based on the type, number and distance of attractors and detractors received.

The original walkscore model does account for the following nine service types as attractions: (1) grocery stores, (2) restaurants, (3) shopping (shopping & business), (4) cafés and bars/pubs, (5) banks (ATMs), (6) parks, (7) schools, (8) books (libraries & book stores), and (9) entertainment (cinemas, sport venues, museums).

3.2. Accessibility Calculation as Web-Service

The system has been designed and developed using a service-oriented architecture. Here, several logical and physical components of the system communicate over the Internet with each other via standardized communication protocols. The various components provide: (i) access to data resources, e.g., transportation network data, point of interest data such as parks, shops and banks, etc.; and (ii) data processing services, e.g., a network routing service, a transit schedule analyzer, a score calculation engine, etc. Use of a service-based architecture allows modifications to the system, e.g., to the accessibility evaluation models, without adversely affecting the system in general. Communication and data delivery between the components is accomplished using standards published by the World Wide Web Consortium (W3C) and the Open Geospatial Consortium (OGC) in general, and the OGC Web Processing Service (OGC WPS) in particular. The geospatial-processing service framework allows implementation and access to several urban accessibility models, e.g. one model for each travel mode (walk, bike, transit), and models with different parameterizations of accessibility score calculation.

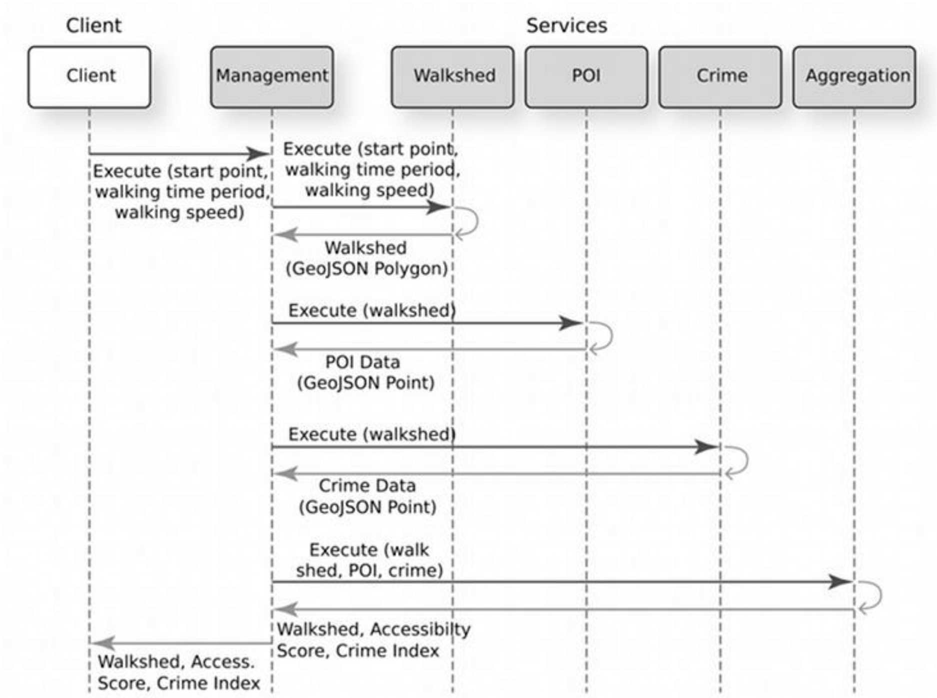

Figure 1: Sequence diagram for the calculation of pedestrian accessibility with WalkYourPlace.

In Figure 1, we show an UML sequence diagram that demonstrates how the WalkYourPlace (WYP) accessibility score is calculated for pedestrian access. The general workflow is similar to the three steps outlined above. In detail the following steps are performed:

- The client application (e.g. a website showing a city map) sends a request to calculate the walkscore for a particular location, travel speed, and travel time to the Management Service. This Management Service invokes the other services necessary for the accessibility calculation in sequential order.
- First, it sends a request to the Walkshed Service, which returns a walkshed polygon (i.e. the accessible area for walking) calculated for the particular location, walk time and walk speed. As outlined in Figure 1, this walkshed polygon is returned in GeoJSON format.
- Afterwards the polygon, i.e. area, is send to a POI Service, which returns a set of "Point of Interest" data, i.e. attractors.
- In the fourth step the Management Service uses the same walkshed to request information about past crimes from the Crime Service, which could be used as detractor information.
- Then, the walkshed polygon, POI data, and Crime data are send to an Aggregation service that evaluates the accessibility of the user-defined location. The Aggregation service will return to the Management Service the walkshed polygon enriched with an accessibility score, polygon area size, and a crime score.
- Finally the Management Service will pass on this information to the client application. We note that this client application could be either a website that displays the results on a map or it can be another service that, perhaps, stores and evaluates the data.

Originally we planned on calculating the access score based on POIs and crime. However, as we haven't found literature on how to account for crime, we decided for now to calculate a separate crime index, rather than combining crime and accessibility scores directly.

3.3 Implementation Details

To realize the system we have developed client and server side software. The browser-based client, shown in Figure 2, uses the JavaScript library Leaflet (leafletjs.com) for map display and interaction with maps. The libraries jQuery and D3.js are employed for user input and display of results. On the server side we run a Linux-Apache-MySQL-Python/PHP configuration for serving webpages, and triggering services that perform the accessibility evaluation. The geo-processing services were wrapped and exposed as standard Web Processing Services (WPS) using the software GeoServer and its WPS module.

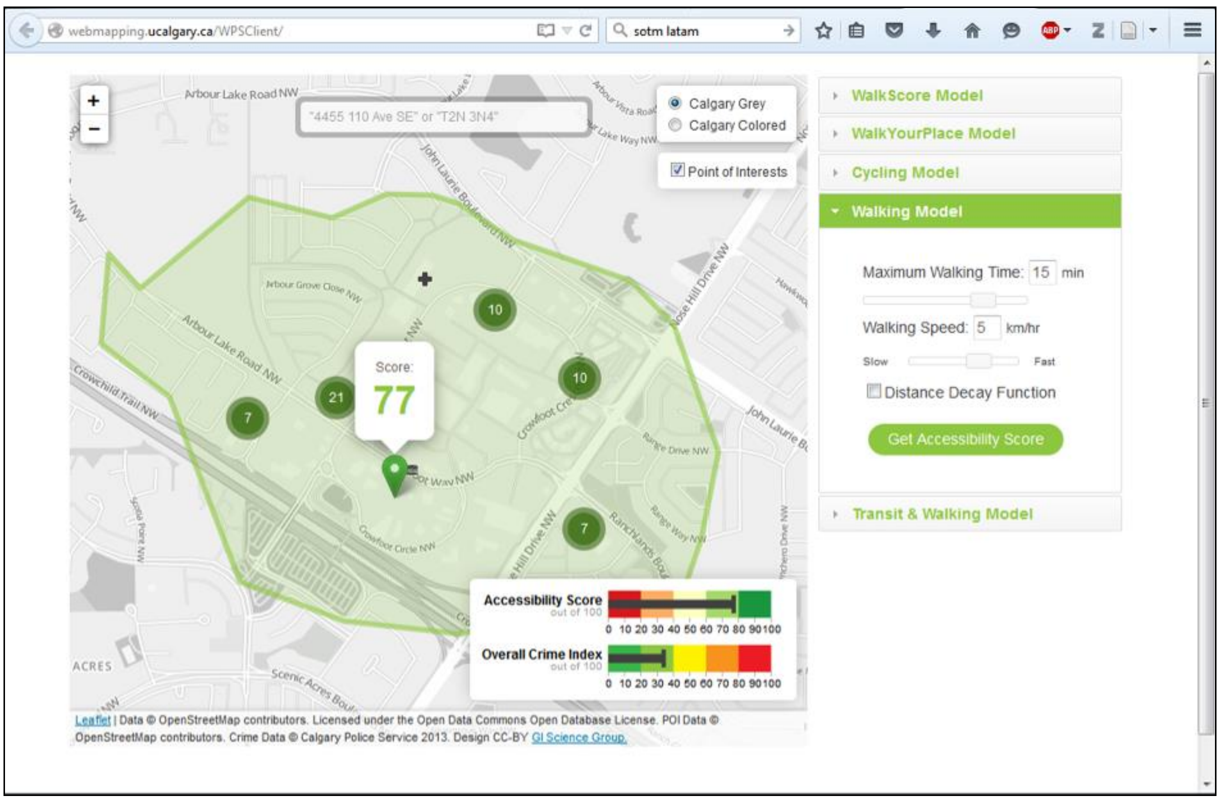

Figure 2: Screenshot of the web client of the WalkYourPlace tool for Calgary, Canada.
http://webmapping.ucalgary.ca/WPSClient/

A central WPS service is the network routing engine that calculates the access areas. The heart of this routing service is OpenTripPlanner (OTP, see opentripplanner.org), an open source software that provides the A* and Multi-Objective A* routing algorithms (Delling, 2009), among other graph building and evaluation tools. OpenTripPlanner permits to evaluate all 3 modes, i.e. walking, biking and use of public transit; but is also able to perform multi-modal routing, for instance trips that transfer from bike to bus. For our WalkYourPlace tool we extend the OTP software to calculated access areas (i.e. isochrones) and to account for steep road/path slopes during the shortest path generation in the walking mode. These improvements where contributed back to the OTP community and are included in the software since OTP version 0.10.

3.2 Data Needs

To perform the calculations we use several datasets, of which most are freely available: OpenStreetMap.org (OSM) provides the road and path data, as well as attractions within accessibility areas. Whereas the road and path data are retrieved as files and converted into a traceable graph by the routing engine OpenTripPlanner, the point of interest data are currently retrieved “live” by using the OSM Overpass-API as a data web service (Olbricht, 2015). For our Calgary prototype implementation we used crime data (i.e. point data) from the Calgary Police website. To evaluate urban transit accessibility public transit schedules are needed that are ideally provided in the General Transit Feed Specification (GTFS) format. The OpenTripPlanner application converts theses schedules into a graph format as well.

4. EXPERIMENTS AND DISCUSSION

We have currently two prototypes of the system running. A first prototype was implemented for Calgary, Canada (see http://webmapping.ucalgary.ca/WPSClient/). A second prototype for further development was setup for Santiago de Chile. An initial set of experiments was carried out with the Calgary prototype with results reported in Steiniger et al. (2013). The main results of these tests have been:

- When comparing circular and network-based accessibility areas, then the area differences can be substantial. The average network-accessible area was 35 % of the circular area, which reduces the number of available attractors, and therefore the score.
- When comparing the effects of travel modes on network-based scores, then we received significant score differences between the travel modes. The mean accessibility score for walking was significant lower than for transit and cycling. For Calgary, the cycling areas and accessibility scores were significantly larger than those for transit.
- Build form has a significant effect on accessibility scores in Calgary: outer suburbs achieved only half the accessibility score (i.e. 20) of “middle-ring” neighborhoods that are closer to the city center (i.e. 42), with inner city areas offering highest walkability (average score of 63).
- Extending the set of attractors of the original WalkScore model by pharmacies and hospitals, as suggested by Doi et al. (2008), did not change scores significantly for Calgary. Perhaps the corresponding weight for these services needs to be increased.
- Using a distance dependent weighting of attractions has a significant effect on score values. This means, care needs to be taken when the form of the curve for distance weighting is determined.

With the Santiago prototype we did first tests to evaluate accessibility for a larger metropolitan area. We calculated walk scores using a pedestrian network model for a point grid containing about 4800 locations. The distance between points has been around 370 meters in North-South direction and 317 meters in East-West direction. Data retrieval and calculation time for a location took at average 6 seconds per point. In Figure 3 we show obtained thematic maps of walkability scores and walkshed area size for Santiago. Pearson correlation between walkability score values and the walking catchment size is 0.52, which is reasonably strong and positive. An explanation for this significant correlation is, however, simple: with a larger walking area the probability of encountering more attractions is higher. When we compared the score values for Santiago with those for Calgary it was also interesting to see that Santiago has several locations for which the maximum accessibility score value of 100 is reached (in dark blue in Figure 3). For Calgary this happened only for a few locations in the city center.

When inspecting the walk score map for Santiago one needs to be cautious. It can be seen that the region in the South West of the city has fairly low walk scores, while at the same time the size of walking catchment seems to be reasonable large. That only a very weak correlation between both variables exists could be indeed related to a lack of attractors. However, as we use open data from OpenStreetMap that is collected though volunteers (Jokar Arsanjani et al., 2015), this could also mean that there is a lack of data in this area, i.e. there are much more in points of interest in reality than in the geographic database.

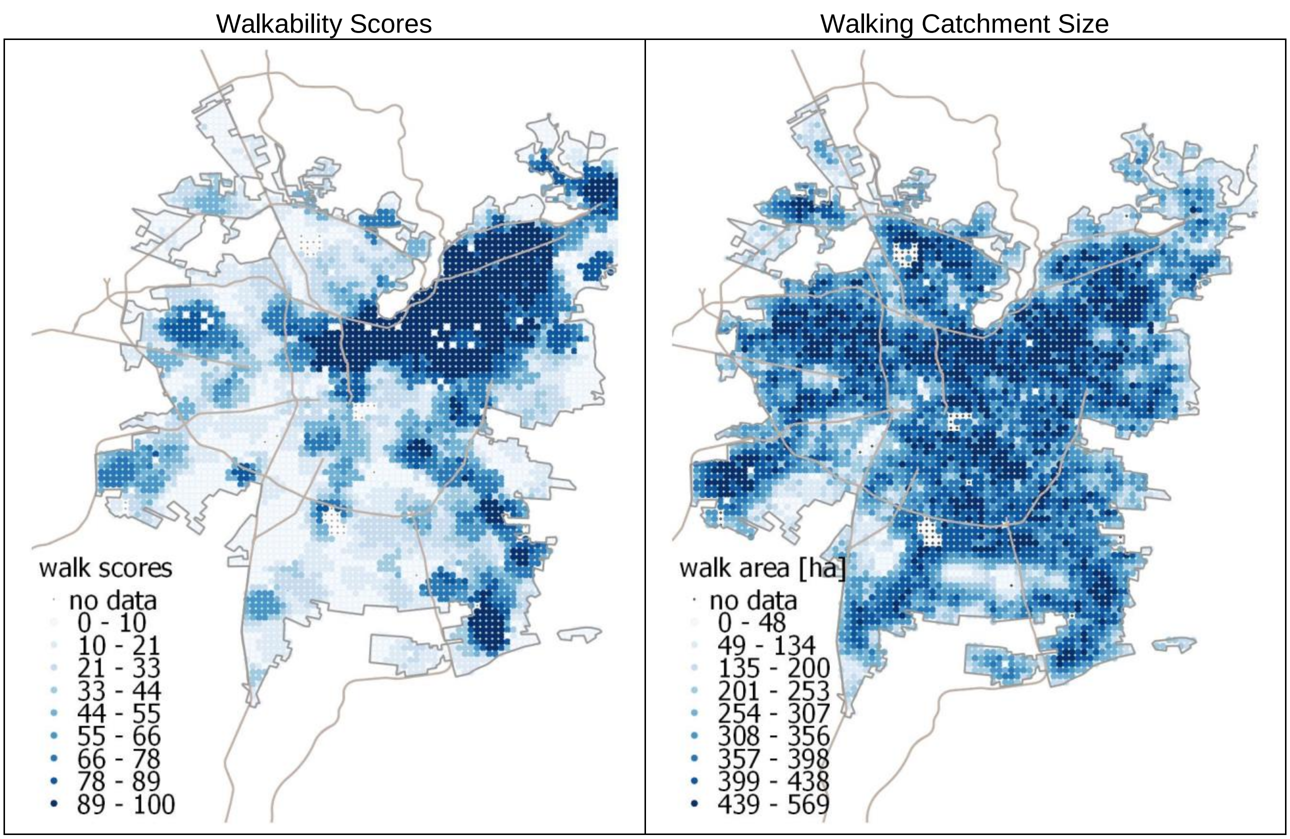

Figure 3: Walk score and walking catchment size maps for Santiago de Chile. Walking was assumed to be 15min with a speed of 5 km/h.

5. CONCLUSIONS

We successfully implemented a web-tool that allows to evaluate urban accessibility. Our earlier experiments for Calgary, reported in Steiniger et al. (2013), show that accounting for different modes of travel (transit vs. walk vs. bike) and different neighborhood generation methods (circle vs. network) brings a more detailed perspective to the topic of accessibility. Our experiment with the Santiago prototype indicate that the approach is also able to create detailed accessibility maps for entire cities - with a very high spatial resolution that can be determined by the user. However, the times for data retrieval and calculation need to be improved since calculation for the Santiago metropolitan region took between 4 and 8 hours at the selected grid resolution of about 350 meter.

The possibility to create detailed accessibility maps opens a range of further analysis options. On a regional scale different cities and metropolitan areas can be compared. On a more detailed scale, accessibility in different parts of the city can be evaluated and this information can be combined with demographic data to evaluate public transportation equity, for instance. On a very fine scale, the method permits to evaluate how accessibility changes when new infrastructure projects are realized, such as the construction of new bike path or a subway line, or when public transit service schedules are changed. Developing and employing the WalkYourPlace system as an analytic tool will be our future direction of research.

ACKNOWLEDGEMENTS

We are thankful to the developers of OpenTripPlanner (OTP), and in particular to David Turner and Andrew Byrd for helping us to get started with OTP. Work on WalkYourPlace was funded by NEPTIS foundation and GEOIDE Canada (Grant TSII 202). Stefan Steiniger was additionally supported by the project “AccesoBarrio” (Fondecyt 1150239) and the Centro de Desarrollo Urbano Sustentable – CEDEUS (Conicyt/Fondap/15110020).

BIBLIOGRAPHY

Adams, D. and S. Tiesdell (2013) **Shaping Places: Urban Planning, Design, and Development.** Routledge, London.

Barton, H., M. Grant and R. Guise (2010) **Shaping Neighbourhoods for Local Health and Global Sustainability.** 2ed, Routledge, London.

Bhat, C.R., S. Handy, K. Kockelman, H. Mahmassani, Q. Chen and L. Weston (2000) **Development of an urban accessibility index: Literature review**. Technical Report. Center for Transportation Research, Bureau of Engineering Research, the University of Texas at Austin. TX-01/7-4938-1.

Crozet, Y., A. Mercier and N. Ovtracht (2012) Accessibility: a key indicator to assess the past and the future to urban mobility. In Geurs, K.T., K.J. Krizek and A. Reggiani (Eds.), **Accessibility Analysis and Transport Planning: Challenges for Europe and North America**, Edward Elgar Publishing, Cheltenham, UK, 263–279.

Crozet, Y. and T. Villalba (2013) Appraisal Methodologies for Transport Investments: How to Introduce an Accessibility Index? Presented at **NECTAR 2013**, Sao Miguel, Azores, Portugal.

Curtis, C. (2011) Integrating land use with public transport: The use of a discursive accessibility tool to inform metropolitan spatial planning in Perth. **Transport Reviews**, 31, 179–197.

Curtis, C. and J. Scheurer (2010) Planning for sustainable accessibility: Developing tools to aid discussion and decision-making. **Progress in Planning**, 74, 53–106.

Delling, D. (2009) **Engineering and Augmenting Route Planning Algorithms.** PhD Thesis, Fakultät für Informatik, Universität Karlsruhe (TH). http://d-nb.info/1013721748/34

DfT – Department of Transport (2007). **Guidance on transport assessment.** Retrieved from https://www.gov.uk/government/publications/guidance-on-transport-assessment

Drummond, W.J., and S.P. French (2008) The Future of GIS in Planning: Converging Technologies and Diverging Interests. **Journal of the American Planning Association**, 74, 161–174.

Doi, K., M. Kii, and H. Nakanishi (2008) An integrated evaluation method of accessibility, quality of life, and social interaction. **Environment and Planning B**, 35, 1098–1116.

Duncan, D.T., J. Aldstadt, J. Whalen, and S.J. Melly (2013) Validation of walk scores and transit scores for estimating neighborhood walkability and transit availability: a small-area analysis. **GeoJournal**, 78, 407–416.

Geurs, K.T., and B. van Wee (2004) Accessibility evaluation of land-use and transport strategies: review and research directions. **Journal of Transport Geography**, 12, 127–140.

Hansen, W.G. (1959) How Accessibility Shapes Land Use. **Journal of the American Institute of Planners**, 25, 73–76.

Harris, M. (2012) Neighborhood 'walkability' a big deal now, even though it's tricky to measure. **MinnPost**. WWW document, http://www.minnpost.com/cityscape/2012/08/neighborhood-%E2%80%98walkability%E2%80%99-big-deal-now-even-though-it%E2%80%99s-tricky-measure

Hunter, A.J.S., S. Steiniger, B.A. Sandalack, S.H.L. Liang, et al. (2012) PlanYourPlace – A geospatial infrastructure for sustainable community planning. **Revue Internationale de Géomatique**, 22, 223–253.

Jokar Arsanjani, J., A. Zipf, P. Mooney, and M. Helbich (2015) **OpenStreetMap in GIScience.** Lecture Notes in Geoinformation & Cartography, Springer International, Cham.

Kwan, M.-P. (1998) Space-Time and Integral Measures of Individual Accessibility: A Comparative Analysis Using a Point-based Framework. **Geographical Analysis**, 30, 191–216.

Manaugh, K. and A. El-Geneidy (2011) Validating walkability indices: How do different households respond to the walkability of their neighborhood? **Transportation Research Part D**, 16, 309–315.

Moudon, A.V., C. Lee, A.D. Cheadle, C. Garvin, et al. (2006) Operational definitions of walkable neighborhood: theoretical and empirical insights. **Journal of Physical Activity & Health**, 3(Sup. 1), S99–S117.

NAR - National Association of Realtors (2011) **Community Preference Survey**. National Association of Realtors. http://www.realtor.org/reports/2011-community-preference-survey

Olbricht, R.M. (2015) Data Retrieval for Small Spatial Regions in OpenStreetMap. In Jokar Arsanjani, J., A. Zipf, P. Mooney, and M. Helbich (Eds.), **OpenStreetMap in GIScience**, LNG&C, Springer International, Cham, 101-122.

Palmer, K. (2012) Young home buyers seek ‘walkability’. **StarTribune**, September 21, sec. Home + Garden. http://www.startribune.com/lifestyle/homegarden/164822116.html

Rubin, J. and D. Chisnell (2008) **Handbook of Usability Testing: How to Plan, Design and Conduct Effective Tests.** 2nd ed. Wiley, Indianapolis.

Stanley, J., and K. Lucas (2013) Workshop 6: The public agenda: What is working and what is missing. **Research in Transportation Economics**, 39, 294–299.

Talen, E. and L. Anselin (1998) Assessing spatial equity: An evaluation of measures of accessibility to public playgrounds. **Environment and Planning A**, 30, 595–614.

Tillema, T., E. Verhoef, B. van Wee and D. van Amelsfort (2011). Evaluating the effects of urban congestion pricing: geographical accessibility versus social surplus. **Transportation Planning and Technology**, 34, 669–689.

WalkScore (2011) **Walk Score Methodology**. WWW document, http://www2.walkscore.com/pdf/WalkScoreMethodology.pdf