Research Report

Transportation Accessibility Advice

Report 1: Literature Review

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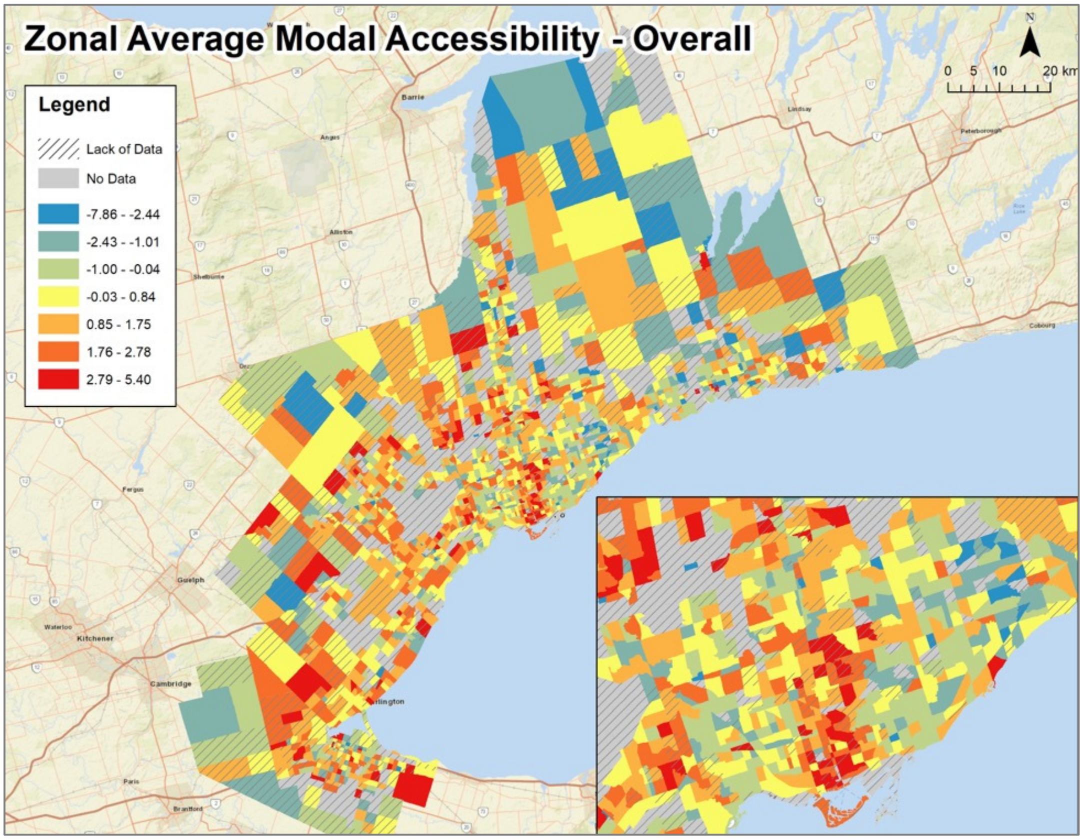
TRANSPORTATION ACCESSIBILITY ADVICE



REPORT 1: LITERATURE REVIEW

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1. INTRODUCTION

Transportation accessibility describes the potential for reaching spatially distributed opportunities while considering the difficulty involved in traveling to them (Páez, Scott, & Morency, 2012). Researchers advocate for accessibility-based planning over traditional mobility-based planning because the former better captures the complex relationships between transportation and land use (Proffitt et al., 2019). The greater versatility of accessibility measures has led to their application in service of a broader range of planning goals, many of which overlap with the strategic goals of the City of Toronto. These include public health (Giles-Corti et al., 2005), sustainability (Handy, 2008), social equity (Martens and Golub, 2018), and economic attainment (Blumenberg and Pierce, 2014), among others.

Accessibility measures fall into four categories depending on whether they are *infrastructure-based*, *person-based*, *utility-based*, or *place-based* (Geurs and van Wee, 2004). Infrastructure-based measures describe the impact of the transportation system on travellers' ability to access destinations, including metrics like time lost to congestion and travel time savings. Person-based measures calculate the number and duration of possible activities that individuals can participate in given their typical time constraints (e.g. work, school), household commitments (e.g. chaperoning children), travel costs, home and work locations, etc. (Fransen et al., 2018). Utility-based measures estimate the consumer surplus, or benefits, that individuals derive from their travel, activity, and residential location choices, reflecting individual preferences, travel constraints, and built form impacts simultaneously (Miller, 2018). Finally, place-based measures examine what is reachable from a location given land use and transport network constraints.

Place-based metrics are the most commonly used group of accessibility measures in transportation planning practice, particularly for regional planning (Boisjoly and El-Geneidy, 2017). They are also easier to interpret, operationalise, and communicate than other measures (Geurs and van Wee, 2004). This paper reviews the growing suite of place-based accessibility metrics and tools with the goal of supporting their use among practitioners in Toronto. It begins with a conceptual overview of different place-based accessibility measures, highlighting their strengths and weaknesses. Then we examine how researchers have improved upon the technical limitations of standard metrics, exploring the state of art in research. After that, we introduce our framework for reviewing accessibility tools and subsequently provide results.

2. AN OVERVIEW OF PLACE-BASED ACCESSIBILITY MEASURES

Placed-based measures calculate accessibility at specific locations across a region. Analysts frequently use the spatial centres, or centroids, of spatial units such as Traffic Analysis Zones (TAZs), Census Dissemination Areas (DAs), Dissemination Blocks (DBs), or grid cells for these analyses. These measures range in sophistication, from simple proximity measures to more complex indicators that account for competition for activities and time of day variation in their availability. This section begins with the most simplistic measures and moves to the most complex, highlighting their strengths, weaknesses, and data requirements.

Proximity or threshold measures. Proximity measures work in two ways. First, they can indicate whether a location is within a given distance of a destination of interest. TTC's service standard of ensuring that all Torontonians are within 400 metres of a TTC transit stop is an example of this type of threshold (Toronto Transit Commission, 2017). Second, these measures can indicate the minimum distance or travel time to the nearest location of a service. For example, healthcare researchers often use distance or travel time to the nearest healthcare facility as a measure of healthcare accessibility. While simplistic, these measures are significantly correlated with patient utilisation of healthcare services in most studies in which they are used (Kelly et al., 2016). Proximity metrics provide the least amount of information as they cannot account for the range, number and diversity of options accessible to travelers within reasonable travel times. They are most often deployed as policy goals, e.g. ensuring a minimum level of service coverage. These measures typically make use of actual distance or times derived from software with a route tool.

Cumulative opportunity measures. These measures estimate the number of opportunities within a given travel time distance of each spatial unit. For example, measures of the number of jobs accessible by transit within 30, 45, or 60 minute thresholds are the most common measures of transportation accessibility used in regional planning (Boisjoly and El-Geneidy, 2017). These measures benefit from their ease of interpretation and development (Geurs and van Wee, 2004), as they only require calculating origin-destination travel times and summing the destinations of OD times below the cut off time. However, they include several drawbacks. First, they do not account for the relatively lower attractiveness of destinations that are further away, failing to reflect how distance influences travel choices, as illustrated in Figure 1. Second, the choice of which temporal threshold to use, e.g. 30 versus 45 minutes, can bias results, as documented in a recent GTA case study (Xi et al. (2018); see Figure 2). These limitations have led researchers to embrace the next group of metrics considered.

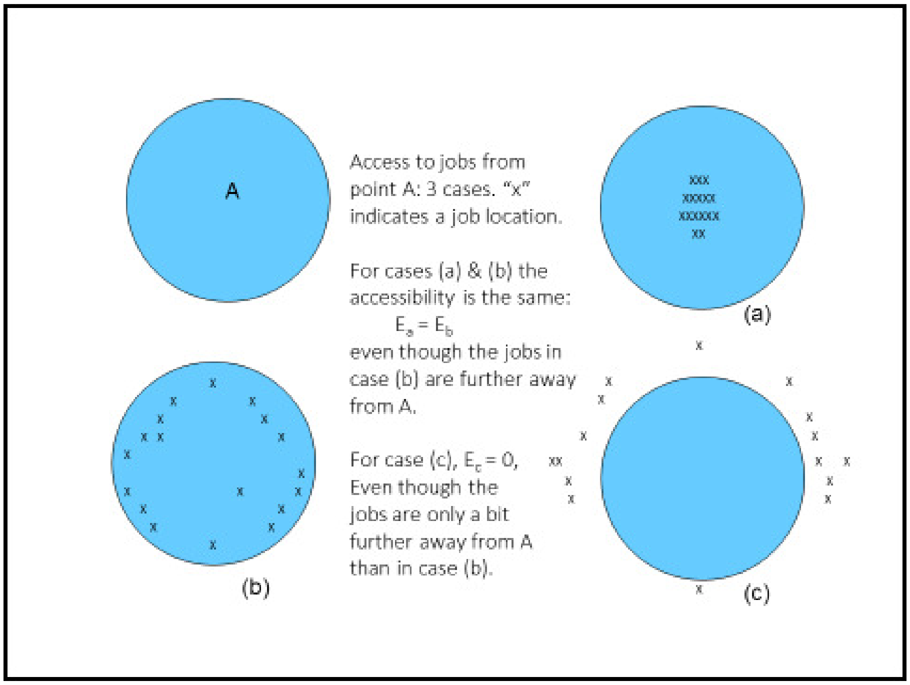

Figure 1. Threshold Effects in Isochrone Accessibility Calculations

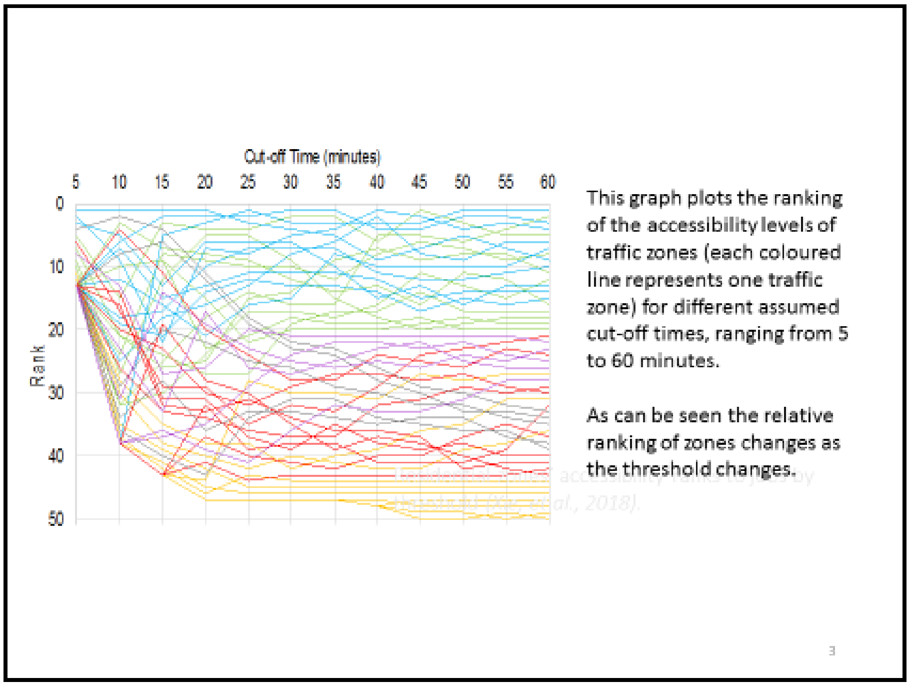

Figure 2. Effects of Threshold Value on Zone Accessibility Rankings

Gravity based measures. These metrics also require the calculation of origin-destination travel times but instead of assigning an arbitrary cut off time, the analyst selects a function that weights the number of opportunities at each destination based on their distance from the origin.

$$A_i = \sum_j O_j f(t_{ij}) \qquad (1)$$

Equation (1) is a generic example of a gravity measure in which the zone i's accessibility (A_i) is the sum of the size (or other measure of the attractiveness) of opportunities at each zone j (O_j), weighted by an "impedance function", $f(t_{ij})$, where f decreases in value as the distance or time between zone i and zone j (t_{ij}) increases. Note that the isochrone (cumulative opportunities) measure is a special case of equation (1) in which $f(t_{ij})$ = 1 for all i-j pairs and zones are only included in the summation if $t_{ij} \le (Threshold)$.

The impedance function weights closer opportunities as greater in value than opportunities further away and are ideally calibrated using observed travel behaviour from the study area. When such data is unavailable, analysts can draw upon functions established in the literature as reasonable predictors of travel behaviour, including inverse power, negative exponential and modified Gaussian forms (Higgins, 2019), as illustrated in Figure 3. Gravity measures do not suffer from the drawbacks of simpler cumulative distance measures; however, the choice of impedance means they are more challenging to specify and more difficult to interpret as the output values are not straightforward counts of reachable destinations.

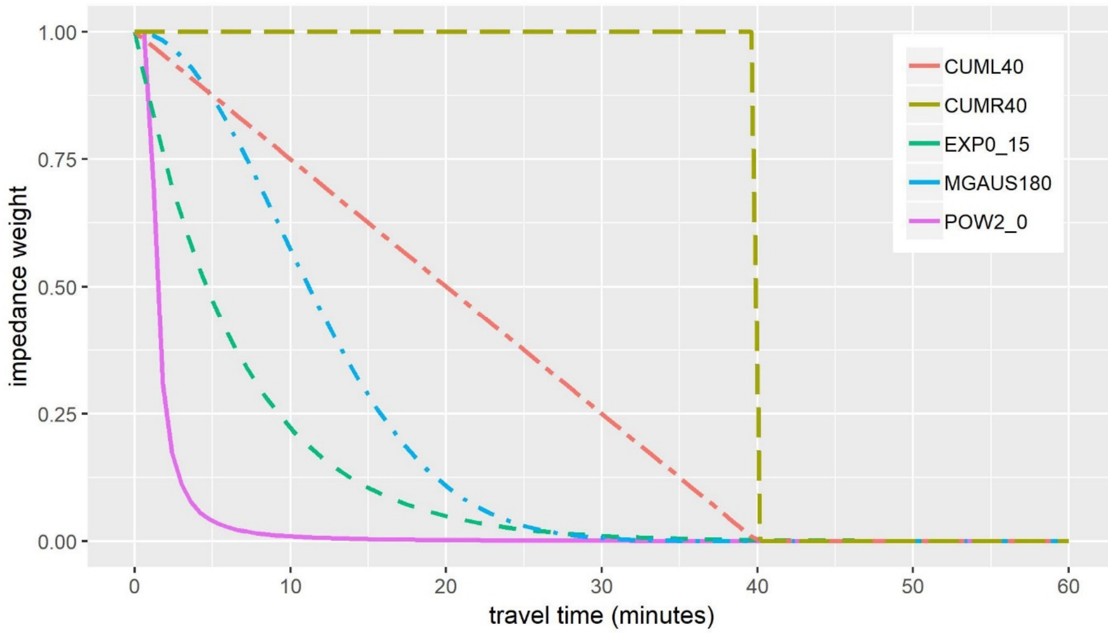

Figure 3. Example Gravity Model Impedance Functions

Transportation and planning agencies across the continent have applied place-based accessibility measures to predict a broad range of likely impacts of their investments and plans. We provide a recent example of each type of place-based metric deployed in project or plan evaluation in Table 1. These examples reflect the growing number of essential activities that planners seek to improve access to when devising plans and evaluating projects.

Table 1. Recent use of place-based accessibility measures by planning agencies

Project/Plan Evaluated	**Policy Area**	**Evaluation Metric**	**Type**	**Outcome/Impact**
Ontario Line, Metrolinx (Toronto, Canada, 2019)	Economic opportunity, education, equity	Percent change in distance-decay weighted job and educational opportunities accessible to both the total population and disadvantaged households	Gravity-model	The analysis demonstrated that the Ontario Line will benefit disadvantaged households within the City of Toronto.
Mobility 2045, North Central Texas Council of Government (Dallas, USA, 2018)	Public health, economic opportunity	Measures impact of the plan on: • Shares of the population within 15 minutes of a hospital, by transit and auto • Shares within 30 minutes of regional shopping generators, by transit and auto	Proximity or threshold	NCTCOG adopted a final Regional Transportation Plan that ensured protected populations did not experience a disproportionate loss of hospital and shopping access due to projected increases in congestion.
Regional Transportation Plan, METRO, (Portland, USA, 2018)	Education, health, community services	Measures impact of the plan on: • The change in the number of “community places” reachable by auto (20 min), transit (30 min), and active travel (20 min). Community places included schools, childcare, healthcare, religious orgs and banks. • The number of low wage and medium wage jobs reachable by auto (30 min), transit (45 min), bicycle (30 min), and walking (20 min).	Cumulative opportunities	METRO’s proposed 10-year constrained investment strategy is estimated to increase the number of community places the average household can access by transit from 78 to 100, and by car from 33 to 57. The agency highlights this evidence in justifying its proposal.
Transport 2025, Transport for London	Employment	Measures impact of the plan on: • The change in the number of jobs accessible by public transit within 45 minutes	Cumulative opportunities	The justification of the adopted scenario highlights that it will increase accessibility across the population by an average of 25%.

Analysis of impacts of population growth on service access (Mayaud et al., 2019)	Education and health services	Competition-based accessibility to walk-in clinics, hospitals and schools in Surrey, B.C. Analysts accounted for competition from other residents using the 2016 Census for a baseline. They replicated the analysis under a 2022 population growth scenario and compared differences in scores to track loss of access.	Competitive	The analysis highlights areas where residents are likely to experience lower access to services due to population growth, helping the city identify where to locate future services.
Southern California Association of Government's 2016 Regional Transportation Plan (SCAG, 2016)	Parks and open-space	Distance decay weighted share of the region's parks and open space reachable within 45 minutes by any transit, 45 minutes by local bus, and 30 minutes by auto. Tested how a proposed Regional Transportation Plan improved these metrics for different socio-demographic groups.	Gravity	The agency's equity summary highlights that the adopted plan will improve residents' access to parks and open space, with benefits accruing to all demographic groups.
The Atlanta Region's Plan (Atlanta Regional Commission, 2019)	Entry level employment	The analysis models the impact of the region's proposed regional transportation plan on the number of low-wage jobs accessible by transit within 60 minutes for disadvantaged communities identified by the agency as "Equity Target Areas" (ETAs).	Cumulative Opportunities	In justifying the final plan, the agency highlights that it significantly increases jobs accessible by transit from ETAs.

3. Technical Dimensions of Place-Based Accessibility Measurement

The place-based metrics described so far can be further refined to better account for other influences on accessibility, including traveller perception, temporal variations in travel times, monetary costs, and competition. These refinements reflect the state of the art in research. We provide an overview of recent improvements to these metrics here.

Traveller perception. Travellers do not perceive the time costs of different components of their travel in the same way. Using the example of transit, travellers perceive walking to stations (access), waiting times at stations, transfer times and waits, and travel to destinations (egress), differently than time spent in transit vehicles (Iseki and Taylor, 2009; Tilahun and Li, 2015; Wardman, 2004). To reflect this, analysts often apply factors that re-weight these times to reflect these perceptions. This requires analysis tools that can accurately estimate these components of the transit trip and weight them accordingly.

Temporal variation. Analysts building place-based access measures must select a departure time, or range of departure times, when building accessibility metrics. Morning and/or afternoon peak periods are often chosen for analysis, given the importance of these periods for work and school commuting, as well as being the periods of peak congestion in the system. Alternatively, to construct a measure that accounts for temporal variability over the entire day accessibility measures can be constructed at one minute intervals throughout the entire day and taking the average value (Farber et al., 2016; Owen and Levinson, 2014). Others suggest calculating the OD travel times at one minute intervals and using the median time for each OD pair to determine if the destination is reachable (e.g. if that median is below the cumulative accessibility cut off time) (Conway et al., 2018).

Competition. For some destinations, such as hospitals or employment locations, accessibility measures may be biased if they do not account for the fact many people may be competing for a limited number of opportunities at those destinations (e.g. available hospital beds, or job openings). For example, while the Toronto downtown has a very large number of jobs, there is also a very large, relatively adjacent labour pool competing for what is still a finite number of jobs. If this competition is not accounted for, the accessibility of workers living near the downtown to jobs may be over-stated, relative to, for example, workers living near smaller employment locations that do not have the same amount of nearby resident workers. Recent research suggests that competitive job accessibility measures better predict individuals' employment outcomes than non-competitive metrics (Merlin and Hu, 2017). Analysts have three options for accounting for competition. The first option controls for the competition of other travelers at origins (Geurs and van Wee, 2004). The second option, in contrast, controls for competition at destinations (Shen, 1998). A third approach accounts for competition at both origins and destinations simultaneously (Merlin and Hu, 2017). Each of these approaches adds a level of complexity that makes resulting values less intuitive to policymakers, however.

Cost. Costs associated with transportation, like fares and fuel, can also limit accessibility. Analysts can devise place-based measures accounting for these costs by constructing generalised accessibility cost metrics. Analysts construct these measures by converting travel times into monetary costs using a value-of-time metric, and adding this to the monetary costs of travel (El-Geneidy et al., 2016). Analysts can then estimate the number of destinations accessible within generalised cost thresholds specified in dollar amounts. This process can also work in reverse, with analysts converting transit fares or vehicle costs into an equivalent time cost that is added onto travel times. The incorporation of monetary costs is important in contexts where transit fares vary by zone, or where roads are tolled. Analysts can also combine the generalised costs across different modes to calculate the maximum accessibility from a given point at varying cost or time levels (Ford et al., 2015; Neudorf, 2014).

Spatial refinements. Finally, the spatial aggregation of accessibility origins and destinations into zones can introduce bias into model results. This is known as the Modifiable Areal Unit Problem in geography. For example, reliance on spatial unit centroids for zonal geographies like DAs implicitly assumes that accessibility for residents within the DA will be constant over the area of the zone when in reality it will vary spatially. This can also occur when aggregating more detailed address-level data to zonal boundaries. Analysts can respond to these biases in several ways. First, increases in computing power mean that disaggregate origins and destinations can be used for accessibility analysis, although such analysis remain very computationally intensive when conducted at the city or metropolitan scale. Second, instead of aggregating address-level destination data to a geography like the DA, they can divide a region into a regular grid of small square or hexagonal cells and assign address-level data to the resulting grid centroids, preserving detailed destination data and minimising spatial bias (Pereira, 2019). Third, analysts with access to detailed land use data can utilise dasyemetric mapping to assign populations and opportunities in an aggregated geography to smaller sub-geographies (Hu and Downs, 2019).

4. Assessment of Place-Based Accessibility Tools

We identified potential tools for use by the city through a search of the academic and grey literatures. This led to the identification of seven primary tools for preliminary evaluation within this review. Some these tools are proprietary commercial products, while others are open source. For some of these tools, analysts have also developed open source packages and add-ons that support accessibility analysis. These primary tools are: ArcGIS, Conveyal, Emme 4, Google Maps, Open Trip Planner, R and Python, and TransCAD. We evaluated each tool for its ability to address the technical dimensions of place-based accessibility described in our review. We considered how an analyst might adapt their workflow if the software lacked a particular function. We also documented the flexibility of their inputs and outputs—e.g. can the tool easily input and output data as csv files and shapefiles, along with their compatibility with GTAModel with respect to complementing the GTAModel's weaknesses and being compatible with GTAModel inputs and outputs. In each category we gave the tool a score that ranged from zero to two (0-2). A two (2) means the tool can compute a given function internally, requiring no outside software inputs or outputs. A one (1) means the tool can accommodate the function as part of a larger workflow. One can also mean that consultants or academics have built plug-ins or add-ons enabling the tool to complete the given task. A score of zero (0) means that the tool cannot assist with a given task

Table 2. Assessment of place-based accessibility measurement tools

	Generates Travel Times	Perception factors	Generalised costs	Impedance functions	Competition	Flexibility of inputs/outputs	Temporal Variation	Spatial Refinements	GTAModel Compatibility	Score
ArcGIS Network Analyst	2	2	1	1	1	2	2	2	2	15
Emme 4	2	2	2	1	1	1	2	2	2	15
Open Trip Planner	2	2	1	1	1	2	2	2	2	15
Conveyal	2	2	2	1	1	1	2	2	2	15
TransCAD	2	2	2	1	1	2	2	2	0	14
R/Python packages	0	1	2	2	1	2	2	2	2	14
Google Maps	2	1	1	1	1	0	2	2	1	11

due to compatibility issues with other software, or due to some other issue. These results are summarised in Table 2 and discussed below. A more detailed evaluation underlying the numerical scores presented in Table 2 is presented in the Appendix.

Four tools all received the highest score. We summarise their strengths and weaknesses before discussing how these findings inform the rest of this project.

ArcGIS's Network Analyst is a component of ArcGIS, one of the most widely used, desktop spatial analysis software in the world. Network Analyst enables users to generate a transportation network using shapefiles and GTFS data. Analysts can execute a range of functions with the resulting network dataset in the ArcGIS environment. These functions can be executed via python script, or via GUIs that allow for detailed specification of network attributes and considerations. Network analyst possess tools that can account for spatial, temporal and perception factors. However, researchers have needed to develop additional add-ons to generate generalised cost measures with ArcGIS (Ford et al., 2015), and to incorporate gravity-measure impedance functions into ArcGIS workflows (Higgins, 2019). Network analyst does not have any built-in functions for calculating competitive accessibility measures.

EMME is a multimodal transportation forecasting software used for zonal-aggregate travel demand modelling. The latest version of EMME allows computation of hard accessibility in terms of generalised cost measures (INRO Blogs, 2019). The tool is sensitive to perception factors and can be deployed to measure travel at different times of day and at different spatial scales. EMME does not allow for direct in-software computation of cumulative opportunity, competition or gravity measures.

Open Trip Planner is a family of open source software written in JAVA that analysts can download and operate on their own computers. OTP uses standardised, open source network datasets to generate travel times, including *Open Streets Map*. The analyst operates these tools using open source coding languages (R, Python). The ubiquity of their data inputs makes them extremely flexible. They can calculate travel times at various scales and repeatedly over multiple time periods. They allow easy application of time perception factors and rely on publicly available, standardised data. They do not, however, provide calculation of generalised cost, gravity, or competition-based measures.

Conveyal is a web-based interface that operates in the cloud and draws on both standard open source network data as well as user-defined inputs. The analyst operates the software through a GUI. This open-source sketch planning tool allows for quick computation of cumulative accessibility measures. Its interface allows for the analyst to edit networks and recompute analysis, enabling quick comparison of alternative planning scenarios. Conveyal's spatial scale is fixed at a very fine spatial grid, however. This tool does not internally calculate competitive accessibility measures, but it does compliment the strengths and weaknesses of the GTAModel.

Three other options received lower scores. We discuss these next.

R and Python are programming environments that allow for complex manipulation of data using user-define functions or pre-prepared functions distributed to users in open source "packages." They can read in and export spatial and aspatial data in diverse formats. As such, they can manipulate travel time matrices with the greatest versatility, and thus receive the second highest score in Table 2. They can enable computation of competition, impedance functions, and variation over time, and can conduct these manipulations jointly. However, R and Python cannot generate network travel times using transit schedules on their own, although packages exist to run Open Trip Planner in R. While R and Python offer the greatest flexibility, they can only serve as tools that augment other travel software. They are thus considered in the phase 2 testing as programming tools to augment/extend other software.

GoogleMaps and TransCAD. These two options scored below 13. Google Maps has an online API that enables travel time estimation. It scores poorly as it does not enable analysts to produce OD times retrospectively. Further, agencies have no control over the network inputs used by Google Maps, making it impossible to use for modeling hypothetical scenarios (Bahman and Levinson, 2020). TransCAD is a sophisticated travel demand modelling software. However, it is not capable of computing competitive accessibility measures and academics have needed to develop add-on tools to enable computation of gravity models using TransCAD outputs (Bhat et al., 2006). The major drawback of TransCAD is its incompatibility with GTAModel. GTAModel was developed in Emme and TransCAD replicates many of the strengths of Emme without complimenting its weaknesses, unlike other tools reviewed such as ArcGIS, Conveyal and Open Trip Planner.

5. Next Steps

Our review has identified three high-performing software tools that compute travel times for accessibility modelling: EMME, ArcGIS and Open Trip Planner. These tools can be combined with R and/or Python scripts to create various “multi-stream” accessibility measurement workflows. We have also identified a “single-stream”[1] sketch planning tool, Conveyal, that can compute the most common metrics and travel times independently, although this greater independence means its outputs are less likely to match findings from a GTAModel-based analysis. We select these four tools as our test cases for further assessment of computation times, interoperability with GTAModel, and usefulness of tool outputs.

Our next step is to apply these tools to a test case to evaluate their relative strengths and weaknesses from a workflow perspective. This will be the subject of the second report.

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[1] So labelled because it is a self-contained tool that does not require development of a multi-software workflow.

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APPENDIX

Assessment of Place-Based Accessibility Measurement Tools—Detailed

	Perception factors	Generalised costs	Impedance functions	Competition	Flexibility	Temporal Variation	Spatial Refinements	GTAModel Compatibility
R/Python packages	1-Provided with an OD Table of wait times and transfers, base R/Python can apply weights.	2-R and Python base programs can calculate generalised cost metrics.	2-Researchers have developed and deployed functions in R and Python (Farber and Allen, 2019; Higgins, 2019)	1-Researchers have used these softwares in competitive (Allen and Farber, 2019)	2-R and Python provided the greatest versatility in ability to read and write different types of files.	2-Researchers have deployed the travel time cube—a minute by minute accessibility measure using these tools (Farber et al., 2016)	2- R packages exist to support dasyemetric mapping and the production of fine spatial grids.	2-Analysts are already utilising python to provide add on analysis to GTA model outputs (Xi et al., 2018).
ArcGIS Network Analyst	2-can be included in network analyst functions (ESRI, 2010)	1-Scholars used Visual Basic to build generalised cost measures off of ArcGIS (Ford et al., 2015).	1-Scholars have built add-ins that enable rapid assessment of impedance functions using ArcGIS (Higgins, 2019)	1-Scholars have used ArcGIS in tandem with other softwares to account for competition in access (Cheng and Bertolini, 2013).	2-enables exports and imports csv, gtfs, and related data products.	2-allows computation of measures over various start times (ESRI, 2010).	2-ArcGIS can calculate accessibility at any spatial scale specified by data inputs.	2-has already been used in tandem with the GTAModel to conduct accessibility analysis (Xi et al., 2018)
EMME 4	2-enables computation of perception factors.	2-can compute generalised cost based accessibility	1-Emme cannot directly compute	1-we could not find any evidence that EMME can	1-EMME can input and output data in most	2-Can calculate travel times at	2-spatial granularity is contingent upon analyst inputs.	2-the GTAModel is built with EMME inputs, making use of

		measures (INRO Blogs, 2019)	gravity-based jobs access measures. Analysts have used EMME inputs in ArcGIS to calculate such metrics (Deboosere, 2018).	conduct competitive accessibility measures.	formats, however its model based GTFS outputs are limited to speeds and headways.	different times of day		this software preferable from a GTAModel compatibility perspective.
Open Trip Planner	2—provides analyst with detailed control over wait times and transfer assumptions (OpenTripPlanner, n.d.).	1—does not compute generalized costs directly, but can be used to calculate such measures.	1—cannot calculate these measures but its outputs can support competition modelling (Allen and Farber, 2019).	1—OTP cannot calculate these measures. But outputs can be used to calculate them in R/Python.	2—utilises open source data provided all transit agencies in the GTA. Outputs data in transferrable formats.	2—OTP can calculate travel times at any departure time specified by the analyst.	2—allows for point level configuration of origins and destinations (OpenTripPlanner, n.d.).	2—Open Trip Planner allows fine grained computation of travel times in formats akin to those produced by GTAModel, allowing easy comparison.
Conveyal	2—Conveyal staff demonstration highlighted the tool's ability to handle wait/transfer penalties.	2—Conveyal staff noted the tool cannot presently produce these measures, but they could be quickly integrated into the software.	1—Conveyal does not presently allow for gravity-based calculations according to Conveyal staff.	1—Conveyal cannot calculate these measures. But outputs can be used to calculate them in R/Python.	1—the tool can quickly model the impact of changes to the transit network. It cannot export GTFS based on sketch planning, however.	2—calculates distribution of travel times within a given departure window. Analyst can set percentile used for access modelling to account for	2—the tool calculates accessibility across a grid where each cell is 300m by 300m (Conveyal, n.d.).	2—Conveyal can utilise GTAModel GTFS inputs to calculate a wide array of sketch planning outputs.

						schedule-based idiosyncrasies (Conveyal, n.d.).		
TransCAD	2—Can include perception penalties for waits, transfers (Caliper Corporation, 2011).	2—can support generalised cost measurement (Caliper, 2019).	1-Academics have developed tools to calculate gravity measures off of Transcad (Bhat et al., 2006)	1—Transcad cannot calculate these measures. But outputs can be used to calculate them in R/Python.	2—TransCAD supports in the import and export of data in a wide variety of formats (Caliper Corporation, n.d.).	2—use of Transcad for different times of day can be established by user inputs.	2-spatial granularity is contingent upon analyst inputs.	0—GTA model is produced in EMME, a product similar to TransCAD. As such TransCAD does not add much value to the GTA model while replicating its limitations.
Google Maps	1- APIs can scrape waits & transfers from directions but analysts have little control over routing assumptions (Google, 2019). No R packages support this function.	1—Times pulled from google maps can be utilised to calculate generalised costs. There are no inbuilt functions for this.	1—outputs can be adjusted with R/Python with impedance functions. The analyst cannot control internal impedance functions used by google in routing (Delmelle et al., 2019)	1— Times pulled from google maps can be utilised to compute these measures but Google Maps cannot.	0-Cannot be retrospective or model proposed service. Analysts cannot control the network used (Bahman and Levinson, 2020).	2—Google maps can calculate time based on needed departure or needed arrival times provided they are not retrospective to the time the analyst is using the API (Google, 2019).	2—Google maps can calculate times at the address level (Google, 2019).	1—Because Google provides its own analytics for estimating travel times with congestion (Google, 2019), google based tools are likely to lack consistency with GTAModel outputs.