Measuring the Gap Between Car and Transit Accessibility

Estimating Access Using a High-Resolution Transit Network Geographic Information System

Itzhak Benenson, Karel Martens, and Yodan Rofé

Accessibility is increasingly identified in the academic literature and in planning practice as a key criterion to assess transport policies and urban land use development. This paper contributes in two respects to the growing body of literature on accessibility and accessibility measurement. First, it proposes a set of accessibility measures that directly relates transit-based and car-based accessibility to each other. Second, it presents a tool based on a geographic information system (GIS) that measures accessibility at a high level of resolution. The tool, called Urban.Access, has been developed as an ArcGIS extension and can be used in urban regions worldwide, provided high-resolution GIS data are available. Urban.Access enables a detailed representation of travel times by transit and car and thus makes it possible to adequately compare accessibility levels by transport mode. The first application of Urban.Access to the Tel Aviv, Israel, region shows substantial gaps between car-based and transit-based accessibility throughout the metropolitan area. The paper ends with a brief discussion highlighting the policy consequences of this finding.

Increasingly, accessibility is identified as a key criterion to assess transport policies, as well as land use developments and urban service delivery policies (*1, 2*). The rise in importance of sustainable development in urban policy has strengthened this trend, as accessibility is a valuable performance criterion from the perspective of each of the three pillars of sustainable development: economic development, environmental quality, and social equity.

From the perspective of economic development, accessibility, understood as the ability of people to reach and participate in activities (*3*), is of key importance because it enables the exchange of people (labor) and goods (products) and hence an efficient functioning of the economy (*4*). From the perspective of environmental quality, the attention is directed toward the differences between transport modes in regard to energy use and environmental externalities (*5*). Here, accessibility is used as a performance indicator of more sustainable modes of transport relative to the private car (*6*). The social justice dimension of sustainable development, in turn, draws attention toward the distribution of benefits and burdens over members of society. Starting from transport as a derived need, accessibility is used in this context as an indicator of the extent to which all groups can participate in activities considered "normal" to their society (*7*). In all cases, accessibility is a key policy indicator, and accessibility measures are a condition sine qua non for adequate policy development.

In this paper the focus is on the environmental and equity dimensions of accessibility. Both dimensions require a measure that enables a comparison between different modes of transport. In the case of the environmental dimension, the comparison is necessary because the main transport modes, private car and public transit, differ substantially in the externalities they generate. From an equity perspective, a comparison between car-based and transit-based accessibility is necessary because, on the one hand, the car tends to provide substantially higher levels of accessibility and, on the other, access to a car is not universal because of barriers inhibiting car ownership and use (costs, legal requirements, and physical abilities).

Below, a set of accessibility measures is developed that make it possible to carry out these comparisons. The paper is organized as follows. A comparative accessibility index is developed in the following section. Next, Urban.Access, an ArcGIS Visual Basic application that has been developed to determine car-based and transit-based accessibility in a detailed manner, is presented. Urban.Access is then applied to analyze the gaps between car-based and transit-based accessibility in the Tel Aviv, Israel, metropolitan area. The paper ends with a brief discussion of the possible policy implications of these gaps.

LOCATION-BASED ACCESSIBILITY INDEX

A wide variety of accessibility measures have been developed during the past decades [see, e.g., Handy and Niemeier (*8*), Geurs and Ritsema van Eck (*9*), and Geurs and van Wee (*10*)]. Geurs and van Wee distinguish between four types of accessibility measures (*10*):

- Infrastructure-based measures, which provide insight into the performance or service level of transport infrastructure (e.g., "the average travel speed on the road network");
- Location-based measures, which provide insight into the accessibility of locations (e.g., "the number of jobs within 30 min travel from origin locations");
- Person-based measures, which analyze accessibility at the individual level taking into account personal possibilities and constraints

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(e.g., "the number of activities in which an individual can participate at a given time"); and

- Utility-based measures, which analyze the (economic) benefits that people derive from access to the spatially distributed activities.

Given the focus on the comparison of car-based and transport-based access, and in line with the majority of studies that compare access by car and by transit, a location-based measure has been developed. Studies that apply location-based measures to assess the differential accessibility by car and transit include Shen (*11*), Blumenberg and Ong (*12*), Hess (*13*), Kawabata and Shen (*14*), and Kawabata (*15*). These and comparable studies focus on access to employment and apply relatively simple estimates of mode-based travel time to compare accessibility levels. The spatial resolution of analysis is usually rather low, with the typical study focusing on census tracts, neighborhoods, or transport activity zones. The calculation of mode-based travel times is often based on data available from transport demand models and transit schedules. For car-based accessibility, this implies that delays due to congestion are often included, whereas for transit, in-vehicle travel time is usually used as the input to calculate transit-based accessibility. Other components of transit-related travel time, such as access and egress times, waiting times, and transit transfer times, are rarely included in the calculations of total transit travel time. In some cases, competition over jobs is included in the accessibility analysis.

The method for comparative analysis of accessibility presented here differs in two respects from previous work in this direction. First, a practically applicable geographic information system (GIS) tool is presented that can be used in metropolitan areas throughout the world to assess car-based and transit-based accessibility. Second, by building on high-resolution GIS data, a technique to make more accurate estimates of transit-based accessibility was developed and, hence, it is possible to reveal existing accessibility gaps in a more detailed manner. The method is based in part on insights from previous studies into accessibility disparities (*6, 15*), as well as from studies on transit quality (*16–18*).

Given the goal to build a practically applicable tool, conceptually simple and easy-to-interpret accessibility measures have been developed. The (dis)utility of the transport component or jobs is not accounted for, nor is possible competition at the individual or group level over transport services or jobs. The proposed measures are computationally intensive and fully employ advanced GIS abilities of high-resolution spatial analysis.

Definition of Transit and Car Access and Service Areas

Following other studies, the measures of accessibility are based on the estimate of the travel time between origin (*O*) and destination (*D*). They are defined for a given transportation mode (*M*): as public bus (*B*) and private car (*C*).

Bus Travel Time

Bus travel time (BTT) equals walk time from origin to a stop of Bus 1 plus waiting time of Bus 1 + travel time of Bus 1 plus [transfer walk time to Bus 2 plus waiting time of Bus 2 plus travel time of Bus 2] plus [transfer component related to additional buses] + walk time from the final stop to destination (square brackets denote optional components).

Noting that walking velocity is essentially lower than that of a car or bus, it is assumed that given the origin *O* and the destination *D*, an agent always starts a trip at a bus stop relatively close to *O* and arrives at a bus stop relatively close to *D*. In what follows "relatively close" is specified as a bus stop at 300-m air distance from a stop, that is, within a 5- to 10-min walk from *O* or *D*.

Car Travel Time

Car travel time (CTT) equals walk time from origin to the parking place plus car trip time plus walk time from the final parking place to destination.

It is assumed that road congestion influences BTT and CTT in the same proportion, that is, if BTT increases with 20% as a result of congestion, a similar increase is assumed for CTT. This is in line with the current Tel Aviv, Israel, situation, in which well-functioning bus lanes that circumvent congestion are virtually lacking.

Access Area and Service Area

Access Area

Given origin *O*, transportation mode *M,* and travel time τ, define mode access area—$MAA_O(\tau)$—as the area containing all destinations *D* that can be reached from *O* with *M* during MTT $\leq \tau$ (MTT = mode travel time).

Service Area

Given destination *D*, transportation mode *M*, and travel time τ, define mode service area—$MSA_D(\tau)$—as the area containing all origins *O* from which given destination *D* can be reached during MTT $\leq \tau$.

Access Area and Service Area as Accessibility Measures

Two main measures of accessibility of the given location are considered, calculated as the ratio of the access or service areas estimated for the two different travel modes.

Given an origin *O*, the bus to car (*B*/*C*) access area ratio is defined as

$$\mathrm{AA}_O(\tau) = \frac{\mathrm{BAA}_O(\tau)}{\mathrm{CAA}_O(\tau)} \quad (1)$$

where

AA = access area ratio,
BAA = bus access area,
CAA = car access area, and
τ = travel time.

Given the destination *D*, the bus to car (*B*/*C*) service area ratio is defined as

$$\mathrm{SA}_D(\tau) = \frac{\mathrm{BSA}_D(\tau)}{\mathrm{CSA}_D(\tau)} \quad (2)$$

where

SA = service area ratio,
BSA = bus service area,
CSA = car service area, and
D = destination.

Equations 1 and 2 can be easily specified for particular type k of destinations D_k or origins O_k and, further, toward including destinations' and origins' capacities $D_{k,\text{capacity}}$, $O_{k,\text{capacity}}$ (say, high-tech enterprises with destination capacity defined as a number of jobs, or low-cost dwellings with origin capacity defined as number of apartments). *B/C* access area ratio to destinations of type k can be defined as the ratio of the sums of capacities of the destinations (e.g., the number of low-wage jobs) that can be accessed during time τ with the bus and car:

$$\mathrm{AA}_{O,k}(\tau) = \frac{\sum_{Dk}\{D_{k,\text{capacity}} \mid D_k \in \mathrm{BAA}_O(\tau)\}}{\sum_{Dk}\{D_{k,\text{capacity}} \mid D_k \in \mathrm{CAA}_O(\tau)\}} \tag{3}$$

where

$\mathrm{AA}_{O,k}$ = access area ratio for origin O and destinations of a type k;
BAA = bus access area;
CAA = car access area; and
$D_{k,\text{capacity}}$ = destination of a type k and given capacity.

Likewise, *B/C* service area ratio for origins of type k can be defined as the ratio of the sums of capacities of the origins (e.g., number of apartments in low-income neighborhoods) that can be accessed during time τ with the bus and car, respectively:

$$\mathrm{SA}_{D,k}(\tau) = \frac{\sum_{Ok}\{O_{k,\text{capacity}} \mid O_k \in \mathrm{BSA}_D(\tau)\}}{\sum_{Ok}\{O_{k,\text{capacity}} \mid O_k \in \mathrm{CSA}_D(\tau)\}} \tag{4}$$

where $\mathrm{SA}_{D,k}$ equals the service ratio for destination D and origins of a type k and $O_{k,\text{capacity}}$ equals the origin of a type k and given capacity.

The sum of the nominators of Equation 3 and Equation 4 is the overall capacity of the access and service areas estimated for the bus mode, and the sum in the denominator is the overall capacity of the access and service areas estimated for the car mode.

The interpretation of Equations 3 and 4 is straightforward. For destinations of type job (j), an outcome like $\mathrm{AA}_{O,j}(1\text{ h}) = 0.3$ would mean that "within 1 h of travel, bus users have access to 30% of jobs compared with car users," whereas for origins of type low-cost (l) apartments, $\mathrm{SA}_{D,l}(1\text{ h}) = 0.3$ would mean that "the number of bus users living in a low-cost apartment that can reach the destination during 1 h of travel is 30% compared with the number of car users that belong to this group." Capacity of an origin or destination can obviously be defined in different ways; in the rest of the paper, capacity of employment is accounted for in regard to total number of jobs.

ESTIMATING ACCESSIBILITY LEVELS WITH URBAN.ACCESS

To implement the aforementioned framework Urban.Access has been developed. Urban.Access is an ArcGIS extension that consists of the proprietary Visual Basic application for estimating access and service areas for both bus and car transport mode and several additional tools that are based on Network Analyst and organized with the help of ArcGIS Model Builder.

Urban.Access makes it possible to construct the areas in the metropolitan region that can be reached by car and transit within a given travel time threshold. On the basis of these areas, it is possible to calculate car-based and transit-based accessibility to different types of land uses or sets of locations. Provided the required data are available, it is then possible to generate general accessibility indices using Equations 1 and 2 and accessibility indices for origins–destinations of particular types accounting for their capacities using Equations 3 and 4.

The Urban.Access GIS database requires the following:

- Layer of roads and, if available, a layer of turns, with the attributes sufficient for constructing a network (Figure 1). The traffic directions and average speed of private car and transit should be provided for each road link, for peak and off-peak hours or at a higher temporal resolution.
- Layer of transit stops and a layer of transit lines. Each line is related to the links and junctions of the road network it passes (Figure 2). The stops of different lines located at the same point in space are considered as different. Each line is related to its stops. Given the dominance of the bus system in the Tel Aviv transit network, the analyses have been limited to the bus system only. However, additional transit modes (e.g., train or light rail lines), if available, can be incorporated into the analysis.
- Table of transit departure and arrival times.
- Layers of urban land uses and, if available, a layer(s) of origins–destinations with capacities given (optional). These layers enable estimating accessibility of specific land uses and origins–destinations, by types and in respect to their capacities, as given by Equations 3 and 4.

These layers and table are necessary for estimating transit and car access and service areas.

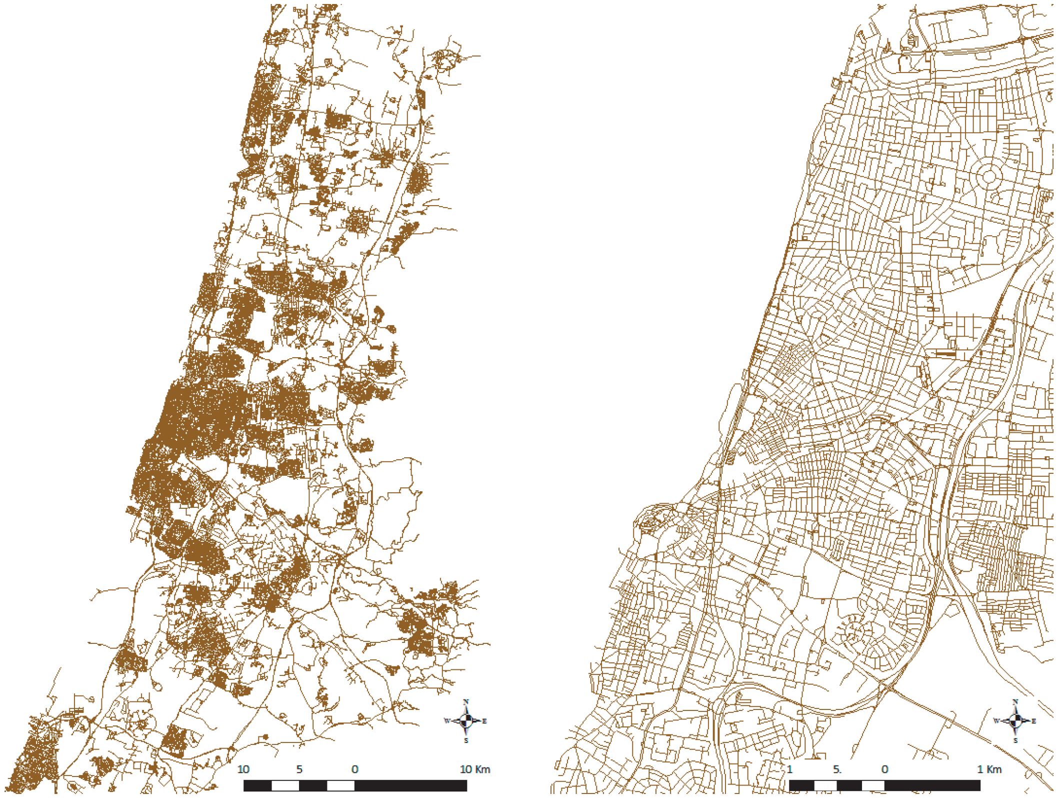
In the preprocessing stage, Urban.Access constructs a table of transfers on the basis of the layers of transit stops and lines and on the table of departure and arrival times. This transfer table contains all pairs of stops and the distance between them in case this distance is below a predefined maximum transfer distance (a maximum walking distance, here set at 300-m air distance). The table is used for estimating possible travelers' transfers between different transit lines. For the Tel Aviv bus network, the table of transfers contains about 2 million records.

The current version of Urban.Access can be illustrated by applying it to estimating the accessibility to urban land uses and jobs in the Tel Aviv metropolitan area on the basis of the access areas index.

Urban.Access Parameters

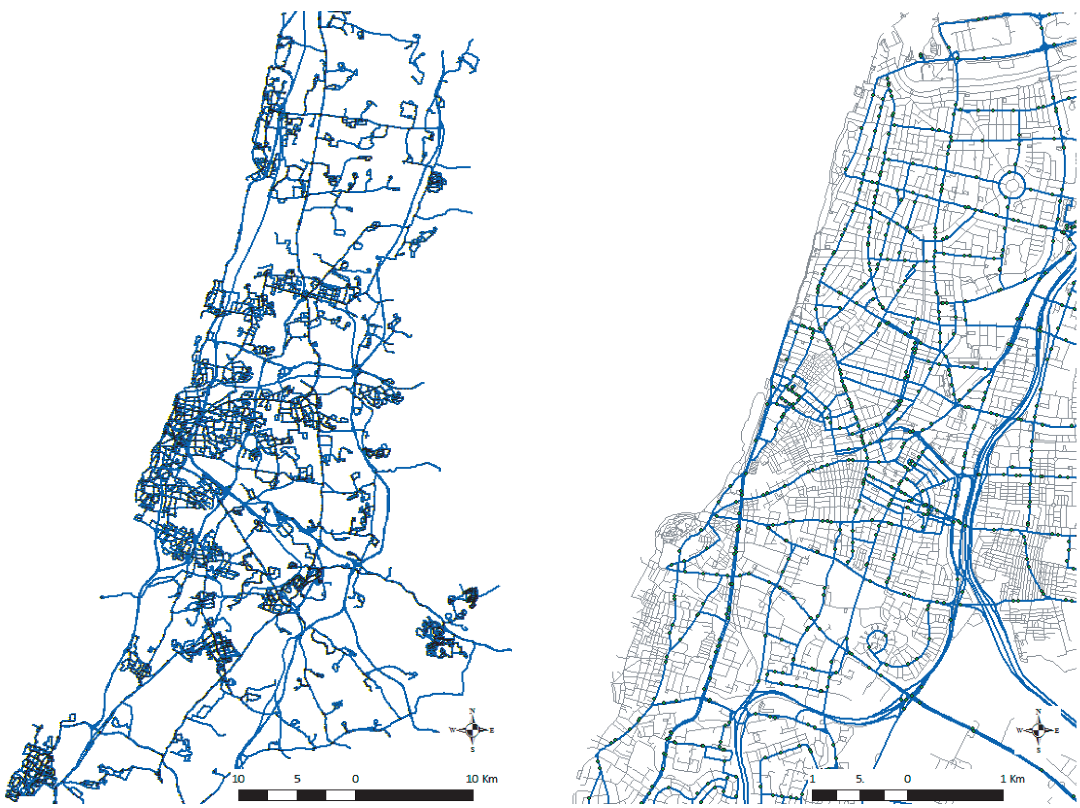
To run Urban.Access, the user has to select an area of origin or destination and then define, via a graphic user interface (GUI), a number of parameters (Figure 3):

- Day of the week. This is necessary because bus timetables vary by day of the week.
- Trip start and finish time. In the case of an access area, this parameter defines the time an agent arrives at the initial bus stop/parking place and starts waiting for a bus or driving. In case a service area is calculated, this parameter denotes the time an agent aims at arriving at a stop within the area of destination (and continues to the final destination by foot).
- Maximal waiting time at initial stop. If an agent waits at the start for longer than the predefined maximum time, the trip is canceled.



(a) (b)

FIGURE 1 Overview of road network in (*a*) Tel Aviv region and (*b*) city of Tel Aviv.



(a) (b)

FIGURE 2 Overview of layers of bus lines and stops in (*a*) Tel Aviv metropolitan area and (*b*) city of Tel Aviv, superimposed on layer of metropolitan road network.

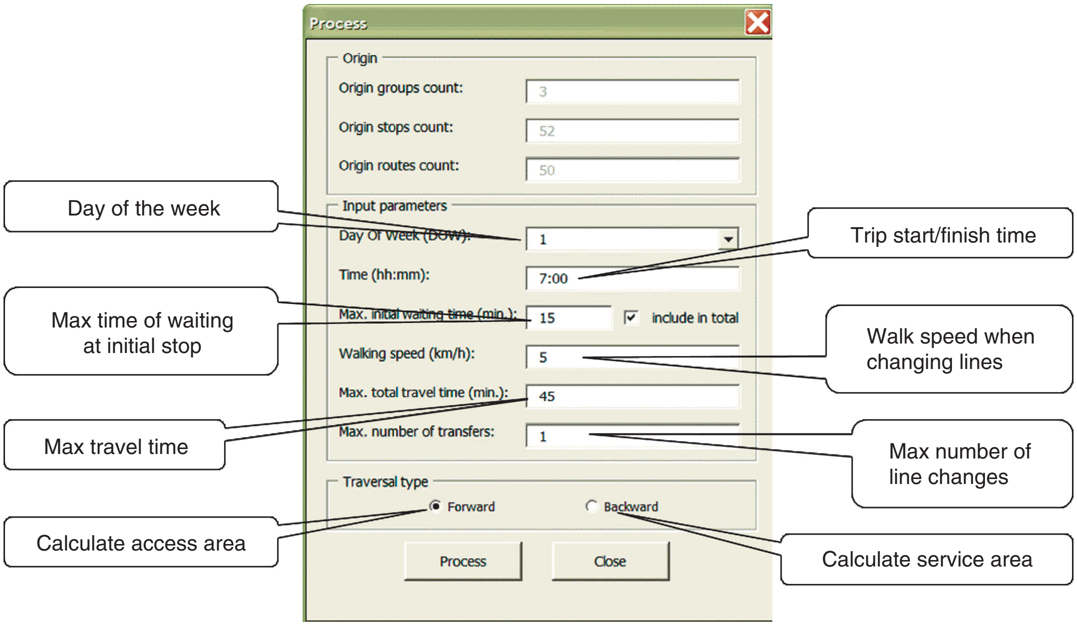


FIGURE 3 Urban.Access application dialog box, with access area ratio chosen for calculations. Choice of area of initial location of traveler results in three geometrically different stops (origin groups count) that contain 52 stops (origin stops count) of 50 bus lines (origin routes count) passing through selected area.

This parameter is interpreted as representing the knowledge about the time schedule at the initial stop. A maximal waiting time equal to, say, 15 min, means that the traveler is sure that the bus arrives not later than 15 min after she arrives at the stop.

- Transfer walk speed. This is used for estimating the time necessary for transfer between bus stops, as well as the access time to the initial bus stop and egress time to the destination.
- Access or egress walking distance. The maximum distance a person is willing to walk to the first and from the last bus stop (not included in the GUI dialog in Figure 3).
- Maximal total travel time (i.e., travel time threshold). The maximal allowed travel time excluding the time necessary to access the transit system or to walk to the final destination from the final bus stop.
- Maximum number of transfers between bus lines vary among 0, 1, or 2; 1 transfer is the default value.
- User has to choose whether either access areas or service areas are estimated.

Urban.Access uses the Network Analyst extension of ArcGIS software; the latter was chosen to fit the software choice of the Tel Aviv municipality.

The use of advanced transportation software, such as TransCAD, would demand reprogramming of the application, but could benefit from TransCAD built-in abilities, such as its ability to find the optimal bus travel path between two stops.

Example of Urban.Access Calculations

Figure 4 provides an example of the results generated by the Urban.Access application. It gives the access area for the Afeka neighborhood, at 07:00 a.m. on Monday, for a travel time threshold of 45 min, a maximum of one transfer, and a maximum walking distance to the initial bus stop of 300-m air distance.

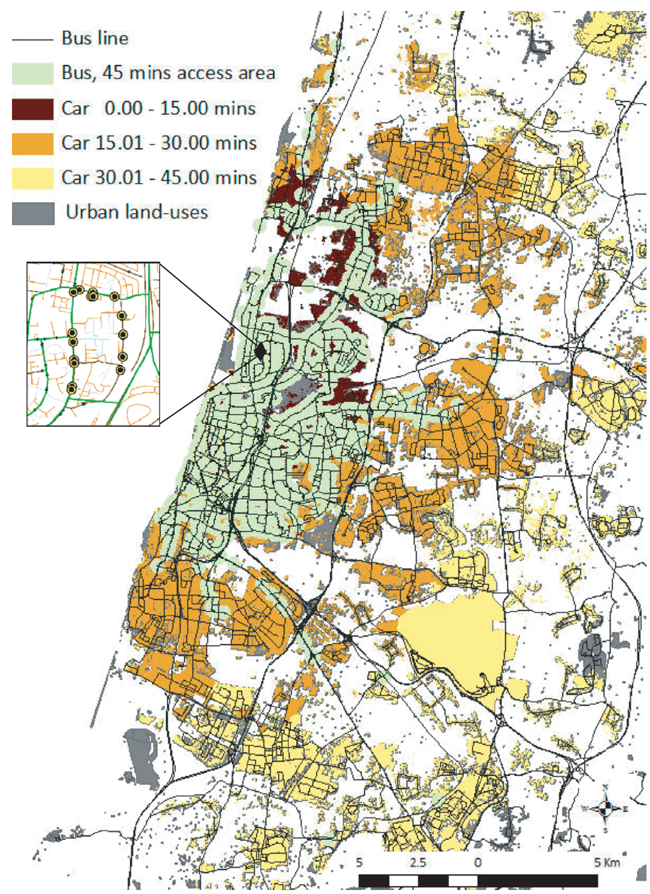


FIGURE 4 All bus stops inside traffic zone that contains Afeka neighborhood and 45-min bus and car access areas for all origins in area, with car access area distinguished according to three 15-min thresholds.

TABLE 1 Access Area Indices $AA_O(\tau)$ for Urban Land Use Destinations as Dependent on Travel Time and Time of Day (7:00 a.m. versus 12:00 noon)

	Travel Time Threshold									
	30 min		40 min		50 min		60 min		Mean	
Type of Trip	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon
Direct trip	0.069	0.047	0.057	0.041	0.052	0.040	0.048	0.040	0.057	0.042
One transfer	0.167	0.099	0.167	0.110	0.186	0.127	0.206	0.153	0.182	0.122
One transfer–direct trip	2.420	2.106	2.930	2.683	3.577	3.175	4.292	3.825	3.193	2.905

NOTE: Lower numbers point to larger gaps between car-based and transit-based accessibility.

The overall bus and car access areas for the urban land uses, presented in Figure 4, are 64 km^2 and 273 km^2. Their comparison enables estimation of the bus to car access area index [$SA_O(\tau)$ index] for a 45-min travel time threshold (excluding the initial and final pedestrian walks):

$$SA_O(45\,\text{min}) = \frac{64\ \text{km}^2}{273\ \text{km}^2} = 0.23$$

Urban.Access thus shows that transit-based accessibility from the Afeka neighborhood is nearly four times as poor as car-based accessibility, if access to all urban land uses is taken into account.

Urban.Access Versus Traditional Transport Modeling Tools

The Urban.Access tool and underlying method to calculate car and transit-based accessibility differ from comparable approaches that could be used with standard travel forecasting methods [e.g., de Dios Ortuzar and Willumsen (*19*)] and software (such as TransCAD). Indeed, travel forecasting tools rely on optimal path algorithms; when employed to generate transit-based accessibility, these algorithms demand substantial calculation time. The approach here does not use these algorithms and, thus, is essentially faster.

APPLICATION OF URBAN.ACCESS: TEL AVIV METROPOLITAN AREA

Urban.Access has been applied to analyze the accessibility gaps in the Tel Aviv metropolitan area for urban land uses and employment. The first results of this analysis are presented below.

Accessibility Gaps for Urban Land Uses and Employment

The Urban.Access application makes it possible to estimate accessibility for any partition of the urban area, thus providing insight into the size of the gaps between transit-based and car-based accessibility over the metropolitan area. The results of Urban.Access in regard to the average accessibility gap for urban land uses and for employment for both peak and off-peak hours are presented.

The accessibility gap for urban land uses is shown in Table 1. This roughly estimates access to residential and industrial areas, as well as to leisure areas and services, and thus provides an indicator of the general level of accessibility. As might be expected, the variation of accessibility is very high: the coefficient of variance (CV = standard deviation ∗ 100%/mean) is about 80% to 90% for each of the values presented in Table 1 and in Table 2.

Table 1 clearly shows that transit-based accessibility is substantially lower than car-based accessibility. During peak hours, transit serves about 6% of the total amount of urban land uses served by car when only direct transit trips are allowed, and about 18% in the case of one transfer. During off-peak hours, these values decrease to about 4% and 12%, respectively. These differences are a direct consequence of lower bus frequencies in the off-peak hours, resulting in longer waiting times at the initial bus stop and higher transfer times.

The results furthermore show that the bus to car access area index [$AA_D(\tau)$ index] does not improve with an increase in the travel time threshold if no transit transfer is allowed. When one transfer is allowed, the index continuously increases, from a value of 17% to 21% for the peak and from 10% to 15% for the off-peak hours. These findings can, again, be linked to the higher frequency of buses during the peak hours.

Table 2 shows the results of the analysis of accessibility to employment in the metropolitan area. As in the case of all urban land uses,

TABLE 2 Access Area Indices $AA_{O,\text{employment}}(\tau)$ for Employment Destinations as Dependent on Travel Time and Time of Day (7:00 a.m. versus 12:00 noon)

	Travel Time Threshold									
	30 min		40 min		50 min		60 min		Mean	
Type of Trip	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon	7:00 a.m.	12:00 noon
Direct trip	0.119	0.083	0.102	0.077	0.102	0.080	0.106	0.086	0.107	0.082
One transfer	0.263	0.169	0.266	0.193	0.308	0.231	0.356	0.287	0.298	0.220
One transfer–direct trip	2.210	2.036	2.608	2.506	3.020	2.888	3.358	3.337	2.785	2.683

NOTE: Lower numbers point to larger gaps between car-based and transit-based accessibility.

there is a substantial gap between transit-based and car-based accessibility to employment. On average, transit travelers can reach up to 20% to 30% of the employment opportunities available to the car user. It may come as no surprise that the accessibility gap to employment is substantially smaller than the one found for all land uses. As in most urban regions, transit services to employment centers are relatively well developed in the Tel Aviv region. However, at the same time the figures show that transit captives can still access far fewer employment opportunities than car owners. This substantial gap is ascribed to the changes in the transport–land use system during the past decades, during which new employment centers have developed on the urban periphery, often along highways, while transit services have lagged behind and still serve primarily traditional radial connections between residential areas and the centers of the cities in the region.

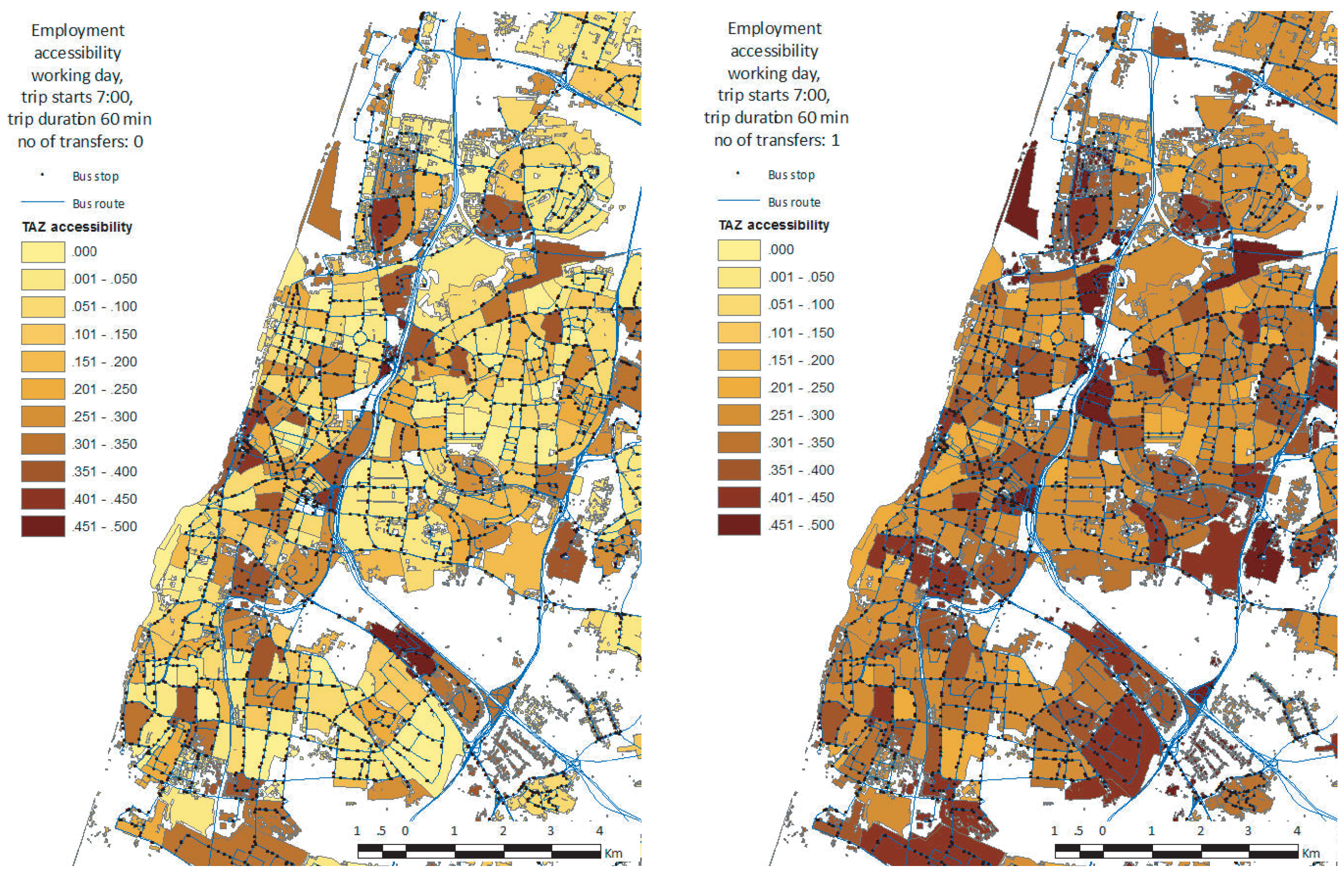
Variation in Accessibility Gaps in Metropolitan Area

The results presented above provide only a general picture of the accessibility gaps in the Tel Aviv metropolitan area. To gain further insight into the accessibility gaps, the GIS maps that Urban.Access generates are presented. For reasons of space, the analysis is limited to accessibility to employment.

Figure 5 presents a typical map generated by Urban.Access. It presents the bus to car access area indices at the level of transport activity zones (TAZs) at peak hours. (Note that the use of the access area index, i.e., the ratio between transit-based and car-based accessibility areas, at least in part eliminates the problem of the decrease in accessibility level close to the boundary of a study area because areas outside the studied region for both transit and car are not included in the calculations.)

According to the map, most of the TAZs show a large accessibility gap, especially if no bus transfer is allowed. Even if one transfer is allowed, more than half the population has transit access to less than 30% of the employment that is accessible by car from the same area (Table 3).

The accessibility pattern for direct trips and one transfer are basically similar. Large gaps can be found in the peripheral areas, as well as in a number of central city areas. No TAZ is served better by transit than by car, even in peak hours. This latter situation is in contrast to the situation in some Asian cities, where transit-based accessibility is actually better in some areas than car-based accessibility [see Kwok and Yeh (*6*)]. Note that despite the fact that the above analysis is performed for 1-h travel time threshold only, it remains valid for other travel time thresholds and times of day. Indeed, the correlations between the values of accessibility for time thresholds of 30, 40, 50, and 60 min is very high and varies between 0.85 and 0.95. The accessibility of most of the areas is relatively high or low, irrespective of the threshold time of travel.



(a) (b)

FIGURE 5 Gaps between transit-based and car-based accessibility to employment for center of Tel Aviv metropolitan area, at resolution of TAZs, for: (*a*) direct transit trips only and (*b*) transit trips that include one transfer, for trip starting at 7:00 a.m. and travel time threshold of 60 min.

TABLE 3 Share of TAZs and Population by Level of Access Area Index

	Share of TAZs (%)		Share of Total Population (%)	
Access Area Index	Direct	Transfer	Direct	Transfer
0.000–0.10	53	17	63.3	30.3
0.101–0.20	34	10	28.9	13.8
0.201–0.30	12	9	7.8	8.0
0.301–0.40	1	11	0.0	8.9
0.401–0.50	0	23	0.0	21.6
0.501–1.00	0	30	0.0	17.5
Total	100	100	100.0	100.0

NOTE: Trips start at 7:00 a.m. and travel time threshold = 60 min.

DISCUSSION OF RESULTS

The application of Urban.Access to the Tel Aviv metropolitan area shows that large gaps exist between car-based and transit-based accessibility for a vast majority of the travel activity zones. The values are somewhat larger than those found by for example, Blumenberg and Ong (*12*) or Hess (*13*), which can be explained by the fact that Urban.Access can capture travel times by transit in more detail. Although other cities or regions may show smaller gaps in accessibility, it may be expected that a more detailed accessibility analysis using Urban.Access will reveal substantial disparities between car-based and transit-based accessibility in most Western cities.

Large gaps in accessibility levels pose substantial challenges for policy makers. From an equity perspective, the question can be raised as to whether the current gaps do not provide a serious barrier for transit captives to participate in the activities considered "normal" by their society, such as access to employment and essential services (*7*). In this sense, results of the Urban.Access application to the Tel Aviv region add to the qualitative nature of most studies on transport and social exclusion [see Lucas (*20*)] and suggest that the contribution of transport to processes of social exclusion may well be larger than is sometimes assumed.

From an environmental perspective, the possibilities to achieve a substantial modal shift toward transit seem bleak as long as accessibility gaps remain so large. In the Tel Aviv situation, only a small share of the total population currently has a truly competitive alternative to travel by private car. This suggests that calls for a more sustainable transport system will remain rhetoric as long as no massive investments are made in transit. A consistent policy effort will be required, including essential changes in the transit lines and timetables over the entire metropolitan area. Without such massive investments, modal shift will necessarily remain limited to some types of trips (home-to-work trips), at certain hours of the day (peak hours), and certain corridors (those traditionally well-served by historical transit routes).

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