Public Transport Accessibility Levels for Ahmedabad, India

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Abstract

Public transport plays an important role in a city's economy and its social equity. It is also instrumental in reducing automobile dependence and traffic congestion. Several factors must come together to achieve well-functioning public transport systems. One major factor is the level of accessibility offered by the public transport system. To better understand and consequentially enhance accessibility, we must be able to measure it and map it, which is the key aim of this paper.

The methodology in this study, which was originally developed by the London Borough of Hammersmith and Fulham and later adopted by Transport for London (TfL) has been adapted to the case study city of Ahmedabad, India. A GIS mapping tool was used to generate a visual representation of public transport accessibility levels (PTAL) taking into account average walk speed and time, distances to public transport stops, and peak-hour route frequencies of different public transport modes. The paper concludes with initiation of a discussion on the potential uses of PTAL mapping to enhance planning practice, such as formulating development/master plans with land use–transport integration, prioritizing public transport and supporting investments, formulating parking policies, and developing transit-oriented zoning regulations.

Keywords: Public transport; accessibility; Ahmedabad; PTAL

Introduction

In 2011, urbanization across the world was 52%; for developing countries, it was 47%. Urbanization is growing at a rapid pace (United Nations 2012) and is expected to reach 56% by 2030. In India in 2011, it was 32% (Census of India 2011) and has occurred at an alarming rate (just 17% in 1951); it is expected to be around 35% by 2021 (Singh 2012).

The Indian economy grew at 6% per annum during the 1990s and at about 8% during the 2000s (Bhagat 2011). Cities and towns play a vital role in promoting economic growth and prosperity and generate more than two-thirds of the country's income and account for 90% of government revenues (Singh 2012). As per India's Eleventh Five-Year Plan, the urban sector contributes about 62% of GDP (Bhagat 2011). There is also a growing realization that an ambitious goal of double-digit GDP growth rate fundamentally depends upon the vibrancy of urban areas in India (Bhagat 2011).

Over the last two decades, bigger cities in India are experiencing higher growth. This has put tremendous pressure on infrastructure systems and has raised questions on the ability of Indian cities to absorb the rapid growth. Urban transition is considered a major challenge, requiring a massive expansion in urban infrastructure and services (Bhagat 2011). Public transport systems already are experiencing the pressure, which is likely to increase. Efficient, comfortable, safe, fast, and affordable urban transport systems are necessary to enhance the advantage offered by cities in economic growth. In addition, the benefits of effective public transport systems also permeate to improve the quality of life and make cities more livable and sustainable (Planning Commission of India 2011).

Currently, public transport systems in India are ineffective at many levels. The rapid growth of India's urban population has put enormous strains on all transport systems (Pucher et al. 2004); they are congested and unreliable, lack spatial network coverage, and have not been able to cope with the rising demand. The availability of transport infrastructure is not only inadequate but also used sub-optimally in Indian cities. The area occupied by roads and streets in Class I cities (population more than 100,000) in India is only 16% of the total developed area, whereas the corresponding figure for the U.S. is 28% (Singh 2012). Most bus and train services are overcrowded, undependable, slow, inconvenient, uncoordinated, and dangerous. Moreover, public ownership and operation of most public transport services has greatly reduced productivity and inflated costs. India's cities desperately need improved and expanded public transport service (Pucher et al. 2004).

Accessibility to the public transport system is the key to improving the level of service in line with rising demand. To improve accessibility, it is important to be able to measure it as accurately as possible. Better understanding of accessibility levels of the public transport systems will not only be necessary to improve the level of service but also to plan and budget for resources (capital costs, operations & maintenance costs, etc.).

Literature Review

Various disciplines define accessibility in different ways. One meaning of accessibility is the ease by which physically-challenged people can access the various elements of the built environment (including transport infrastructure); this study is not concerned with this type of accessibility. The other definition comes from geography and transport disciplines. Geographers define accessibility as the relative ease of reaching a particular location or area in the city. Hansen (1959) defines accessibility as the potential of

opportunities for interaction with emphasis on the intensity of the possibility of interaction rather than just ease of interaction (Hansen 1959). Murray et al. (1998) distinguish between the terms “access” and “accessibility” and suggest that “access” is the opportunity for use based on proximity to the service and its cost, whereas “accessibility” is the suitability of the network to get individuals from their system entry point to their system exit location in a reasonable amount of time (Murray et al. 1998).

This study focuses on accessibility to public transport, which, in turn, provides accessibility to various destinations in the city. When considering definitions particular to public transport accessibility, the idea is emphasized in Hillman and Pool (1997), as cited in Joyce and Dunn (2010), who make a distinction between “local” and “network” public transport accessibility. Local accessibility is the accessibility of a particular location to a public transport system; network accessibility is the accessibility of locations in a city by the public transport system. The public transport accessibility levels (PTAL) concept essentially addresses local accessibility, but indirectly also incorporates network accessibility by using route and frequency data. A study by Litman (2008), as cited in Joyce and Dunn (2010), attempts to incorporate both aspects by defining public transport accessibility as the quality and ease of transit service at a particular location.

The key objectives of this study were to measure PTAL (excluding paratransit modes), map it, and initiate a discussion of its importance in application to enhancing planning practice. Several studies have made considerable progress on developing service indices to measure transit accessibility.

Different measures have been designed to reflect differing points of view. Some measures of public transport accessibility focus on local accessibility and consider both spatial and temporal coverage. The Time-of-Day tool developed by Polzin et al. (2002), as cited in Mamun and Lownes (2010), is a measure that considers both spatial and temporal coverage at trip ends. In addition to the inclusion of supply-side temporal coverage, this tool overtly recognizes and considers the demand side of temporal coverage by incorporating the travel demand time-of-day distribution on an hourly basis. This integration makes the tool distinctive to public transport planners. The *Transit Capacity and Quality of Service Manual* (TRB 2003), as cited in Mamun and Lownes (2010), provides a systematic approach to assessing transit quality of service from both the spatial and temporal dimensions. The transit level-of-service (TLOS) indicator developed by Ryus et al. (2000), as cited in Mamun and Lownes (2010), provides an accessibility measure that uniquely considers the existence and eminence of pedestrian routes connected to stops. It also combines population and job density with different spatial and temporal features to measure transit accessibility. This tool emphasizes various aspects (walking distance and access to stops, wait time at stops, availability of service at user’s required time) in the consideration of accessible public transport service by a person.

The Land Use and Public Transport Accessibility Index (LUPTAI) seeks to measure how easy it is to access common destinations (e.g., health, education, retail, banking, employment) by walking and/or public transport. This is in contrast to the traditional

method of measuring accessibility by road distance and is the first of its kind to consider public transport as a means of access rather than a facility to be accessed (Pitot et al. 2005). A new travel time-based method to visualize and analyze transit service coverage—a computer application called the Time-Based Transit Service Area Tool (TTSAT)—was developed as a new approach to mapping transit accessibility by incorporating total trip travel time into the transit service area maps it generates. To make these travel-time estimates realistic, TTSAT integrates all segments of a complete, door-to-door transit trip into the trip time calculations. TTSAT's mapping and analysis capabilities offer numerous potential applications for planners, developers, and members of the public working to create transit-accessible communities. TTSAT users can customize the time-based transit service area (TTSA) maps they generate by specifying details of passengers' expected travel behavior, such as walking speed or the maximum time they are willing to spend going to and from public transport stops (Cheng and Agrawal 2010).

This study uses the PTAL calculation method developed by the London Borough of Hammersmith and Fulham in 1992, which was later adopted by Transport for London (TfL), as the standard method for calculation of public transport accessibility in London (Transport for London 2010). In addition to the UK, public transport accessibility ratings are used in a number of countries such as the U.S., the Netherlands, Australia, and New Zealand (Joyce and Dunn 2010). The methodology in this paper was appropriately adapted from London (Transport for London 2010) to fit Ahmedabad data.

Ahmedabad and Its Public Transport

The city of Ahmedabad, India, was founded in AD 1411 and is the largest city in Gujarat and the seventh largest in India, with a population of 6.35 million in 2011 (Census of India 2011). Ahmedabad has two major public transport systems: the Ahmedabad Municipal Transport Service (AMTS), a bus service running in mixed traffic, and the BRTS, operated by Ahmedabad Janmarg Ltd (AJL), which runs on dedicated corridors (except junctions and a few other links). Both AMTS and BRTS are wholly-owned subsidiaries of the Ahmedabad Municipal Corporation (AMC). A metro rail system called the Metrolink Express Gandhinagar Ahmedabad (MEGA) has been proposed and is in the advanced stages of planning. Figure 1 shows the public transport network in Ahmedabad.

FIGURE 1.
AMTS, BRTS and Metro routes

Note: Routes shown are those used in the calculation of PTAL per the existing routes of AMTS and BRTS in 2013 and the proposed routes of MEGA in the same year. However, some alignment changes and new routes have been proposed thereafter.

Ahmedabad has a high percentage of population living in slums. According to the Ahmedabad Urban Development Plan 2011 (AUDA 2002), in 1998, 32% of the city's population lived in slums, with 60% of these households falling below the poverty line. According to the Global Report on Understanding Slums (2003), the percentage of Ahmedabad housing categorized as slums increased from 17% in 1961 to 23% in 1971 to 26% in 2011. One study suggested that 40% of Ahmedabad's population lives in slums (informal settlements) and chawls (tenements) (Somani 2011). The modal share in Ahmedabad is 17% public transport (all buses) and 54% non-motorized transport (NMT) (walking and cycling) (LGBC 2001). This suggests that a very high percentage of the urban poor population cannot afford public transport for commuting. Mapping public transport accessibility levels can be a useful tool in achieving the goal of improving the level and quality of service of public transport system (including the upcoming metro rail system).

Overview of London PTAL Methodology

PTAL is a detailed and accurate measure of the accessibility of a specific point to the public transport network, taking into account walk access time and service availability. It measures the accessibility level for a specific point (origin) considering the accessibility index (AI) for all available modes of transport from that point. The inclusion of total access time to measure the level of accessibility is an important feature of this method (Mamun and Lownes 2010). The methodology is briefly described below, broken down into key steps for calculation. For a more detailed explanation, please refer Transport for London (2010).

Step 1: Define points of interest (POI) and service access points (SAP) – POI is defined as a point for which the accessibility level is to be measured with reference to an SAP, which is a public transport stop (such as bus stop, metro station, etc.).

Step 2: Calculate walk access time from POI to SAP – The actual road network distance from POI to SAP is measured and, assuming a walk speed of 4.8 km/h, walk time (WT) is calculated. The maximum walk times for bus and metro rail are 8 and 12 minutes, respectively. Any SAPs beyond these distances are not taken into account to calculate PTAL for that particular POI.

Step 3: Identify valid routes at each SAP and calculate average waiting time (AWT) – The valid routes are bus and metro routes for the peak hour (8:15–9:15 AM),¹ and the frequency of services on all these routes during this hour is used in the calculation of AWT.

AWT is defined as the period from when a passenger arrives at an SAP to the arrival of the desired service. In the calculation, the hourly frequency (f) is halved because the scheduled waiting time (SWT) is estimated as half the headway. For example, a 10-minute service frequency (6 buses per hour) would give an SWT of 5 minutes. In addition, to make the calculations more realistic, a “reliability factor” (K) is added to the SWT depending on the transport mode, which is assumed to be 2 minutes for buses and 0.75 minutes for rail services (see Equation 1):

$$AWT = 0.5 \frac{60}{f} + K \quad (1)$$

Step 4: Calculate minimum total access time (TAT) for each valid route at each SAP – This is done as shown in Equation 2 by adding times obtained in steps 2 and 3.

$$TAT = WT + AWT \quad (2)$$

¹ This assumption leads to a PTAL map for the peak period only, which is also followed for this study.

Step 5: Convert TAT into equivalent doorstep frequency (EDF) – This is obtained as 30 divided by TAT (see Equation 3)². The principle is to treat access time as a notional average waiting time as though the route was available at the doorstep of the selected POI.

$$EDF = 30/TAT \quad (3)$$

Step 6: Obtain the accessibility index (AI) for each POI – In this step, the most dominant route, i.e., the route with the highest frequency, is assigned the weighting factor of 1.0; for all other routes, a weighting factor of 0.5 is assigned. Thus, for a transport mode (m), the AI_m is calculated as shown in Equation 4:

$$AI_m = EDF_{\max} + 0.5 \sum_{\text{all other routes}} EDF \quad (4)$$

Then, the accessibility index for a POI (AI_{POI}) is calculated, as shown in Equation 5:

$$AI_{POI} = \sum_m AI_m \quad (5)$$

Step 7: Map PTAL – The AIs obtained for each POI are allocated to eight bands of PTAL, as shown in Figure 2 (where Range of Index means AI of the POI). A POI with a value of 0 indicates no access to the public transport network within the parameters given and is not colored on the map.

FIGURE 2.
London PTALs

PTAL	Range of Index	Map Colour	Description
1a (Low)	0.01 – 2.50		Very poor
1b	2.51 – 5.00		Very poor
2	5.01 – 10.00		Poor
3	10.01 – 15.00		Moderate
4	15.01 – 20.00		Good
5	20.01 – 25.00		Very Good
6a	25.01 – 40.00		Excellent
6b (High)	40.01 +		Excellent

Source: *Transport for London (2010), Table 3, p. 6*

The calculation steps in the methodology are the same as the London PTAL methodology. However, for mapping of PTALs in Ahmedabad, the parameters and assumptions considered in the London PTAL methodology were altered to suit the conditions of Ahmedabad.

² The reason for dividing 30 (minutes) by TAT is that it re-applies the half-the-headway rule. This is applied twice because the values have different meanings. In the Step 3, frequency is converted into AWT, and in the Step 5, TAT is converted back into a frequency (EDF). The first step calculates TAT, i.e., the time it takes to leave home/point of origin and get on a service. This is made up of three elements: walk time + AWT (assumed to be half the headway) + reliability factor. TAT is now converted into a number that is comparable to service frequency but that takes into account the additional walk time taken to reach the stop along with reliability. Thus, the half the headway rule is applied again to TAT in Step 5 to give the doorstep frequency.

Data Collection

To adapt the London PTAL methodology to Ahmedabad, data listed in Table 1 were needed. However, in some cases, the data were not available and, therefore, were collected by field observation and map measurements in GIS software.

TABLE 1.
Data Types and Sources

Sr. No.	Data Type	Source
1	Ahmedabad city base map (satellite image)	Google Earth
2	AMC boundary limit (GIS shape file)	Prepared by authors from information available on AMC website
3	AMTS bus stop locations (GIS shape file)	CEPT University study
4	AMTS bus routes (GIS shape file)	Prepared by authors from route information on AMTS website
5	AMTS peak hour bus frequency	Available from this report (AUDA, Government of Gujarat 2011)
6	BRTS bus stops locations (GIS shape file)	Prepared by authors from Google Earth
7	BRTS bus routes (GIS shape file)	Prepared by authors from the route information on BRTS website
8	BRTS peak hour bus frequency	Available from this report (AUDA, Government of Gujarat 2011)
9	MEGA metro station locations (GIS shape file)	MEGA office (available in .kml file format)
10	MEGA metro routes (GIS shape file)	Prepared by authors from route information on MEGA website
11	MEGA peak hour metro frequency	MEGA office

AMTS – Ahmedabad Municipal Transport Service, BRTS – Bus Rapid Transit System, MEGA – Metro-link Express for Gandhinagar and Ahmedabad.

Data collection in developing countries is always a challenge. This study was met with several obstacles, such as refusal to part with data, requiring tremendous persuasion and personal references. Creating the GIS base map and relevant layers (as shape files) also consumed significant initial research time. The authors wish to appeal urban local bodies involved in planning to create public data bases (which could also be a nominal paid service) that are accessible to academicians and practitioners. As a sign of good faith, the authors agreed to share the database and maps created in this study on a website.

Methodology for Calculation of Accessibility Index in Ahmedabad

Given that the Ahmedabad urban agglomeration area is about 1866 km², it was necessary to limit the geographical extent of the study area. Since the public transport services in the urban agglomeration region outside the AMC boundary (465 km²) are minimal, the AMC area was selected as the boundary for the study area.

Within the study area are about 1,300 AMTS bus stops and 175 AMTS bus routes. The BRTS has 104 bus stops within the AMC boundary (as of February 2013). In addition, of the 62 proposed metro rail stations, 36 (as of February 2013) fall in the AMC boundary, which have been considered for the PTAL calculations.

In the London methodology, POIs were considered by built development (e.g., plotwise). However, given the time constraints and data resource limitations—i.e., lack of availability of a building footprint for the study area—this study deviates from the London methodology by dividing the study area into 1 km² grid cells, resulting in 675 grid cells. The centroid of each cell represented the POI for the measurement of the PTAL score of that particular cell. In addition to the data resource constraints, the grid-cell approach made the analysis much faster. The authors believe that the difference in accuracy of input data does not translate into a huge variation in PTAL mapping; since the application of PTAL was sought at a macro-scale (i.e., development/master plan level), the current output based on the grid cell method is adequate. If needed, the application can be easily developed at the local area planning level should building footprint data be available. Also, the fare structure can be considered in the PTAL calculation to further enhance PTAL mapping. However for Ahmedabad, AMTS and BRTS fares are nearly the same and the metro rail is not yet built. If in the future there are different fare structures among these public transport modes for competing services, then the fare structure could be considered in the PTAL calculations.

The next step was reconsidering London PTAL assumptions regarding walk speed, reliability, and peak-hour factors. The majority of the roads in Ahmedabad do not have footpaths and, if any, are usually encroached by street vendors and parking. People are forced to walk on the road (the black-top surface), which creates unsafe and potentially hazardous situations, such that walking is avoided as much as possible, even for short trips. Therefore, walk speed was decreased to account for this discomfort. To arrive at a quantitative estimate, a small convenience-based sample was obtained in various neighborhoods of Ahmedabad. The walk speeds ranged from 3.4–3.8 km/h, with a mean of 3.6 km/h. However, the model can be easily updated following a more detailed sample survey. It is clear that the first and last mile connectivity to public transport is predominantly by walk/cycling (i.e., non-motorized transport [NMT]). Tyler (2002) indicates that if the accessibility chain (see Figure 3) is breached (in this case, links 1 and 7 of Figure 3), then a journey cannot be performed. Therefore, improved pedestrian facilities to better facilitate first/last mile connectivity are imperative in public transport accessibility. Should more reliable surveys—by different neighborhoods of Ahmedabad, by age groups, etc.—be conducted in the future, the model can be easily updated.

FIGURE 3.
Accessibility Chain

Source: Redrawn from Tyler (2002)

Bus reliability factors are also increased to account for traffic delays caused due to unpredictable traffic conditions and disobedience of traffic rules. Considering the usual office hours of 10:00 AM–6:00 PM, the peak hour was changed to begin half an hour earlier. The parameter values for Ahmedabad are shown in Table 2.

TABLE 2.
Parameter Comparison for
Accessibility Index Calculation

Parameters	Units	London Values	Ahmedabad Values	
Peak hour	-	08:15–09:15 AM	09:30–10:30 AM	
Walk speed	km/h	4.8	3.6	
Walk speed	m/min	80	60	
Bus	-	London Bus	AMTS Bus	BRTS Bus
Reliability (K)	min	2	2.5	1
Max. walk time	min	8	Not applicable (calculated for each POI using actual road network)	
Max. walk distance	m	640		
Rail	-	Underground, Tram, DLR, Overhead rail	MEGA metro rail	
Reliability (K)	min	0.75	0.75	
Max. walk time	min	12	Not applicable (calculated for each POI using actual road network)	
Max. walk distance	m	960		

POI to SAP distances were measured from Google Earth using the distance measurement tool. Then, using the above parameters, calculations of AI for each of the 675 grid cells were carried out, per the steps outlined previously. Table 3 shows a sample format for calculating AI for a POI. The next step was to assign PTAL bands to AIs.

TABLE 3. Sample Format for Accessibility Index Calculation

POI ID	Mode	SAP Name	Route No.	Distance (m)	Frequency (per hr)	Weight	Walk Time (min)	SWT (min)	TAT (min)	EDF	AI
307	AMTS	Vijay Cross Roads	40/3	338	1	0.5	5.63	32.5	38.13	0.78	0.39
			n th route	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
		Memnagar Tube well stop	200	427	5	1	7.11	8.5	15.61	1.92	1.92
			n th route	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
		n th SAP	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	BRTS	Valinath Chowk	1	824	24	1	13.73	2.25	15.98	1.87	1.87
	MEGA	Vijay Cross Roads	1	300	20	1	5	2.25	7.25	4.13	4.13
	Total (AI for a POI 307)										56.41

PTAL Mapping

After calculating the AIs for all the POIs, the next important step is to graphically represent the values in a format that is easily interpreted by policymakers. The AIs for each POI ranged from 0.78 to 205. An important consideration to further this objective was to make classes/bands of AIs that can be represented by a color code. GIS software with thematic mapping capability was used, which provided four alternatives for classifying the values: 1) equal breaks, 2) natural breaks (Jenks), 3) standard deviation, and 4) quantile breaks. For all methods, the higher the PTAL value, the higher the accessibility. Keeping the number of classes same, the frequency distribution of AIs by the four methods is shown in Figure 4.

As can be seen from Figure 4, the equal breaks method and the natural breaks method produced a skewed or lopsided distribution, with the majority of the lower values concentrated over a few classes. Comparatively, the standard deviation method produced a better distribution of values. However, the quantile breaks method distributed values such that all classes had a nearly equal number of values. The PTAL map of equal breaks, as shown in Figure 5, displayed heavily the color code of level 1 (blue), and very few spaces in the map show the higher level accessibility color code (red). This map seems misleading in terms of accessibility to public transport in Ahmedabad.

FIGURE 4. Comparison of frequency distribution

Considering the other two options of the maps shown in Figure 5 (standard deviation method and natural breaks method), these displayed comparatively better visual output, in which the gradation of accessibility was more visible compared to the map of the equal breaks method, with the map using the quantile breaks method producing the best visualization of gradation of accessibility. The quantile breaks method map had approximately equal distribution of PTAL values among all the defined levels (from level 1 to level 10). This allows areas with high, medium, and low accessibility to be easily identified on a map. Therefore, this method produces the best visual representation of PTAL. In other words, the first three methods under-represented the areas that are known to have a higher public transport accessibility index.

FIGURE 5.
Comparison of Ahmedabad
PTAL maps

The final PTAL map adopted in this study was generated by the quantile breaks methods. This map was the best match with our intuitive understanding (repeated in Figure 6 at a bigger scale). For example, the city center area (east of the river) has the densest public transport routes, which in the first two maps are depicted as the areas with PTALs ranging predominantly from level 6 to level 8, with slightly more levels 8, 9, and 10 in the third map. Although, technically, this is correct given the method of calculation, it seems to override our intuitive understanding. Given a choice of the four methods in GIS software, we propose quantile breaks as the best candidate that visually depicts PTAL that aligns our intuitive understanding.

FIGURE 6.
Final Ahmedabad PTAL map

Observations from Ahmedabad PTAL Map

From the final Ahmedabad PTAL (Figure 6), it was found that the accessibility to public transport services is excellent in the core city area, as expected, and gradually becomes poorer moving away from the city center. Also, there are few scattered, leap-frogged areas with excellent PTAL surrounded by medium PTAL; these areas represent newer commercial development with a high level of road connectivity (which is also used by public transport). This pattern connects well with the radial pattern growth of the city. Urban sprawl in the city is occurring in radial form. The accessibility levels in the outskirts of Ahmedabad are poor along Sardar Patel Ring Road, which is on the periphery of the city limits of Ahmedabad. These areas of low accessibility to public transport are the areas dominated by higher-income households. In such areas, the dominant mode of transport is private vehicles; there is less dependency on public transport modes and, hence, the accessibility levels to public transport are poor. However, the BRTS system, which is currently in an expansion phase, is extending the connectivity to these areas which will, in turn, improve the accessibility index in such areas. Moreover, the completion of construction of metro rail routes (MEGA) also will improve the accessibility index of these areas once the trains are operational.

Conclusions and Recommendations

Providing public transport service and the supporting infrastructure will not fulfill public transport's full potential. The system must offer high accessibility geographically and to all sections of society. Commuters and other tripmakers will consider public transit as an option for tripmaking when the system is properly accessible to and from their trip origins/ destinations (spatial coverage) and when service is available at preferred travel times (temporal coverage).

Accessibility refers to people's ability to reach goods, services, and activities, which is the ultimate goal of most transport activity. Many factors affect accessibility, including mobility (physical movement), the quality and affordability of transport options, transport system connectivity, mobility substitutes, and land use patterns. Conventional planning tends to overlook and undervalue some of these factors and perspectives. More comprehensive analysis of accessibility in planning expands the scope of potential solutions to transport problems. Therefore, PTAL maps are an easy and smart representative tool for accessibility.

PTAL maps such as those generated in this study can be of a value for urban and transport planning authorities:

1. PTAL maps can be used by development/master planning authorities to integrate land use zoning with public transport accessibility—a very important aspect usually ignored by Indian planners (Balachandran et al. 2005). A more detailed critique of the urban planning process in Ahmedabad can be found in Adhvaryu (2011). By allowing future transport improvements to be incorporated into PTAL calculations, a future PTAL map becomes an important tool in supporting land use and zoning decisions for local authorities. It can also be useful in testing “what if” scenarios using land use and transport integration model (e.g., see Adhvaryu 2010).
2. PTAL maps can be used to improve the existing public transport system by recognizing areas with poor accessibility, thereby enabling decisionmakers to prioritize investments in public transport systems and support NMT facilities.
3. Parking policies can be formulated using PTAL maps. For example, park-and-ride facilities can be provided to supplement areas with low and medium PTAL, and parking may be restricted or charged at a higher rate in areas with high PTAL.
4. PTAL mapping can help cities that are planning to introduce transit-oriented development (TOD), as PTALs already incorporate walkability criteria from POIs, an important D (distance to transit) in the 6Ds of TOD (Cervero and Ewing 2010).
5. Several sections of society can use PTAL maps. Households can use them to inform their residential location choices, especially low-income households that are captive public transport users. Real estate developers (who supply housing and commercial spaces) can use PTAL maps (both existing and future) for locating potential sites, especially low-income housing. Government agencies can use PTAL maps to locate housing for economically weaker sections.

Given the ease of building and updating the PTAL model, as and when new public transport and NMT facilities are built, the methodology overall has significant potential to become a useful tool as a decision support tool for urban and transport planning. The authors are in the process of initiating a dialogue with local planning agencies to discuss application of this study as a planning support decision tool.

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