DEVELOPMENT OF OPPORTUNITY-BASED ACCESSIBILITY INDICATORS

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ABSTRACT

Accessibility, defined as the ease (or difficulty) with which activity opportunities can be reached from a given location, can be measured using the cumulative amount of opportunities from an origin within a given amount of travel time. These indicators can and should be used in regional planning and modeling efforts that aim to integrate land use with travel demand. The primary objective of this paper is to illustrate the creation of realistic space-sensitive and time-sensitive block level accessibility indicators to support the development of the Southern California Association of Governments activity-based travel demand model.

Key words: accessibility, activity based model, GIS, Poisson regression models, time of day factor

INTRODUCTION

Accessibility indicators are needed for a variety of regional planning and modeling purposes, such as characterizing quality of life (*1*), describing transportation quality of service (*2*), explaining travel behavior choices (*3, 4*) and intra-household task allocation (*4*), predicting short and long term decisions in multiple contexts (*5*), and measuring "jobs-housing" balance (*6*). Accessibility indicators also serve several other purposes, as enumerated and discussed in detail by Geurs and van Wee (*7*).

A general definition of accessibility is the ease (or difficulty) with which activity opportunities may be reached from a given location using one or more modes of transportation. Defined in this way, accessibility indicators (or measures) incorporate the performance of a transportation system and the spatial distribution of land-use activities within a given region. In essence, accessibility captures the extent of attractiveness of each potential destination and weights that attraction by the associated travel "cost" to reach the destination from a given location. The travel "cost" itself may be represented explicitly in the form of an impedance measure to reach the destination from the origin point (as is the case with gravity-based formulations of destination choice behavior) or implicitly in the form of a cumulative accounting of opportunities that are within a certain travel time from the origin point. This latter formulation is particularly attractive and intuitive, because it represents the "intervening opportunities" or amount of activity potential reachable within a given amount of travel time from an origin location. One can identify different travel time thresholds (e.g., 10 minutes, 20 minutes, and 50 minutes) and create geographic "buffers" within which activity opportunities that can be reached are counted. In this manner, the accessibility formulation is both a function of land use patterns and the performance of the transportation system, and provides a compact measure to examine the impact of land use policies in computer simulation scenarios or in before-after infrastructure project studies. At the same time, the accessibility formulation can also be used to evaluate the extent of distributional justice, measure spatial (in-)equity in the provision of opportunities, and provide indicators of the overall cost of reaching work places, shopping centers, and social and recreational opportunities.

The techniques to construct accessibility indicators based on the "intervening opportunities" formulation have evolved from very simple calculations to more complex and detailed methods that use algorithms within a Geographic Information Systems (GIS) platform to extract and assemble data from multiple spatial databases at very fine levels of spatial resolution. Lee (*3*) and Kwan (*8*) have pioneered the computation of such GIS-based accessibility indicators, and we extend their concepts to develop accessibility indicators for a very large metropolitan area. Our ultimate objective is to use these accessibility indicators as explanatory variables in long term choice (e.g., job location and car ownership) and short term choice (e.g., daily activity patterns) model systems. We also envision using these indicators to map the study area and identify centers of activity to eventually perform spatial distribution equity analysis.

The large metropolitan area of interest in this research is the Southern California Association of Governments (SCAG) region, which represents the largest Metropolitan Planning Organization with 19 million residents and 189 cities. However, the methods developed and illustrated here for the SCAG region uses data largely available throughout the United States from agencies that routinely provide information about the spatial distribution of employed persons by industry type and the transportation network that serves them. The unique aspect of our current research is that we combine these readily available "static" sources of data with secondary data on the temporal (within a day) availability of opportunities and the condition of the transportation network to develop dynamic accessibility indicators that vary by time of day. In particular, the outcome of the research here is a set of time-sequenced maps of activity opportunity availability and a classification of the US Census blocks by their access to these opportunities. To achieve this, network and socioeconomic data at a fine level are prepared, and a methodology that integrates spatial/temporal factors reflecting the variation in available opportunities and travel time during the day is proposed.

The remainder of the paper is organized as follows. The next section describes the three major data sources used in the current research effort. This section also includes data processing and preparation details. The following section discusses the methodology for the computation of accessibility indicators, and presents sample maps of accessibility. The concluding section of the paper discusses the advantages and limitations of the proposed accessibility indicators, and recommends directions for further improvements.

DATA USED

The three primary data sources used to generate the accessibility indicators are as follows: (1) geo-coded block group and block data within the SCAG region, (2) SCAG roadway and transit network, and (3) employment data from the Census Transportation Planning Package (CTPP) and Dun & Bradstreet (D&B).

Geo-Coded Block Groups and Block Data within the SCAG region

The block group and block shape files for the six counties in the SCAG region (the six counties are Los Angeles, Orange, San Bernardino, Imperial, Ventura, and Riverside) are available from the Census website (http://www2.census.gov/cgi-bin/shapefiles2009/state-files?state=06). These county-specific shape files were combined to form the complete SCAG region GIS maps for both block groups and blocks. The SCAG region consists of 10,631 block groups and 203,191 blocks. The GIS maps and layers provide the basis to compute block group-specific and block-specific measures, such as area, population, and length of roadway segment by functional classification.

SCAG Roadway and Transit Network

The roadway network with link speeds is a vital database when adding the temporal dimension to the accessibility indicators. The network, embedded in the SCAG four-step model, provides a geo-coded roadway database with roadway link speeds for the AM peak (6am-9am), PM peak (3pm-7pm), off-peak (9am-3pm), and night time (7pm-6am) periods. However, this network does not cover a sufficient number of local roadways to capture the variation in blocks in terms of roadway infrastructure. That is, a denser network with more streets is necessary to obtain good fidelity in the accessibility measures at the block level. To address this issue, the roadway network from the SCAG four-step model was enriched by combining it with the roadway network in Tele Atlas (Dynamap) 2000, which includes the entirety of local roadways. Once enriched, this roadway network GIS layer was overlaid on the block group and block shape files to obtain highway network attributes specific to each block group and block. These block group-specific and block-specific network attributes are used later to obtain block-specific employments, as discussed in the next section. The roadway network is also used in the computation of the time-sensitive accessibility indicators, as discussed further under the "methodology" section.

Along with the roadway network, the SCAG four-step model also has embedded a comprehensive transit network in the region, as shown in Figure 2. This network includes all the transit stops, routes, and headways. Similar to the roadway network, the transit network is associated to the block group and block shape files, thus providing the information needed for developing counts of transit stops located within each block boundary. This information is used subsequently in developing the accessibility indicators, as discussed further in the "methodology" section of the paper.

Employment Data from CTPP and Dun and Bradstreet (D&B)

The measure of activity opportunity, used in the accessibility indicators constructed in this study, is the number of employees "reachable" within a certain time threshold of each block. The CTPP employment data was the primary dataset for obtaining information on the number of employees. Specifically, the CTPP data contains the number of employees within each **block group,** categorized in 14 industry types based on the North American Industry Classification System (NAICS). In addition, the D&B data, containing more than 100 million business records, was used as the supplementary information to verify the CTPP data. The inconsistency between the two datasets in the number of employees at the block group level led to a data matching approach to reconcile the two sources of information as follows:

1. If Diff * <=10, use the number of employees from CTPP
2. If Diff > 10 , use the average of CTPP and D&B data

* Diff = (Absolute number of employee difference between D&B and CTPP)/(Area of block group in squared km)

The D&B data was used to enhance the CTPP dataset in one other way. Specifically, the CTPP data combines the education and health industry types, and provides the total number of employees in both these industries. However, as discussed later, our accessibility indicators account for the fact that the number of employees at a location will vary by time of day, based on the work schedules of the employees. Since the work schedules for those in the education and health industries are likely to be quite different, this should lead to differential patterns of accessibility for education and work activity purposes at different times of the day (for example, one would anticipate that accessibility to health care would be better than accessibility to education during the wee hours of the morning). So, we separate out the numbers of education and health employees according to the proportions for the two industries from the D&B dataset. The final 15 industry types used in our accessibility computations are: a) Agriculture, forestry, fishing and hunting and mining; b) Construction; c) Manufacturing; d) Wholesale trade; e) Retail trade; f) Transportation and warehousing and utilities; g) Information; h) Finance, insurance, real estate and rental and leasing; i) Professional, scientific, management, administrative, and waste management services; j) Educational; k) Health; l) Arts, entertainment, recreation, accommodation and food services; m) Other services (except public administration); o) Public administration; p) Armed forces.

The employment data available from the CTPP and D&B data is at the block group level. However, our objective is to compute accessibility indicators at the finer block level too. This requires the use of a spatial disaggregation mechanism to obtain the employment within each block from the employment within each block group. To do so, we assume that the employment in a block is influenced by the area of the block, the population of the block, and the sum of the roadway segment lengths by functional classification (freeway, primary arterial, minor arterial, collector, and ramp). These block-specific variables are computed by overlaying demographic GIS files over the block shape files, and doing the same with the highway network files (as discussed in the earlier section). However, one first needs to develop a relationship between employment and these independent variables. We use the block-group spatial level for this purpose, and estimate a Poisson regression model for each industry type using the number of employees in the block group as the dependent variable and the variables mentioned above as the independent variables. It should be noted that a variety of regression formulations were used, but the Poisson regression reproduced the observed variation in the number of employees in the most satisfactory manner. Once estimated, we transfer the block-group level regression to the block-level to complete the disaggregation of employment data down to the blocks. A sample estimated regression model for the public administration industry is shown in Table 1. This model shows that all of the independent variables are very highly statistically significant in influencing the number of employees within the block group. Also notable is that some predictor variables (e.g., area, length of freeway and collector segments, and population) have different coefficient signs on the models for different industry types, indicating that these variables play different roles in determining the distribution of employment by industry type.

TABLE 1 Poisson Regression Models for Public Administration (estimated at the block group level)

Variable	Coefficient	Standard Error	t statistics	[lZl>z]
Constant	2.786442	0.00314203	886.828	0.0000
Area	3.444E-10	1.24E-11	27.879	0.0000
Population	1.794E-04	1.32E-06	136.081	0.0000
Total length of freeway sections	-2.281E-05	5.69E-07	-40.098	0.0000
Total length of primary arterials	3.574E-05	2.86E-07	124.843	0.0000
Total length of minor arterials	2.033E-05	3.59E-07	56.592	0.0000
Total length of collector roadways	-3.332E-06	5.91E-08	-56.366	0.0000
Total length of ramp sections	1.724E-04	7.22E-07	238.618	0.0000

Log likelihood function =-704050.2 Info. Criterion: AIC = 132.45381
Chi squared =100262.9 Degrees of freedom= 7
Overdispersion tests: g=mu(i) : 1.802 Overdispersion tests: g=mu(i)^2: 1.055

With these regression models, the block group employment for a certain industry type was distributed into each block within a block group as shown below:

a. Calculate the estimated block employment ($\hat{E}_i$) for block *i* by applying the block characteristics and the estimated regression model

b. Calculate the percentage of employment for each block *i* within each block group *j*.

$$P_i = \frac{\hat{E}_i}{\sum_{i \in B_j} \hat{E}_i}, \text{ where } B_j \text{ is the set of all blocks within block group } j.$$

c. Calculate the block employment by multiplying the percentage with the block group employment

$$E_i = P_i \times (\text{employment in block group } j \text{ that block } i \text{ belongs to}).$$

The same process was repeated for 10,631 block groups and 15 industry types. Figure 1 illustrates the education employment disaggregation for block groups located in the Santa Monica area. The color intensity of green in the map represents the number of employees. A light green shade implies a lower number of employees within the block/block group, while a dark green shade implies a higher number of employees. The top part of the figure is drawn to scale, and shows the block group level layer on the left and the block level layer on the right. Note that the observed pattern of employment for the block group level and the estimated employment pattern at the block level are consistent with one another. The bottom part of the figure is not drawn to scale, but is drawn to focus in on one particular block group. The right side of this part of the figure shows how the block group employment has been disaggregated to different numbers of employment within blocks belonging to the block group.

FIGURE 1 Employment disaggregation at block level.

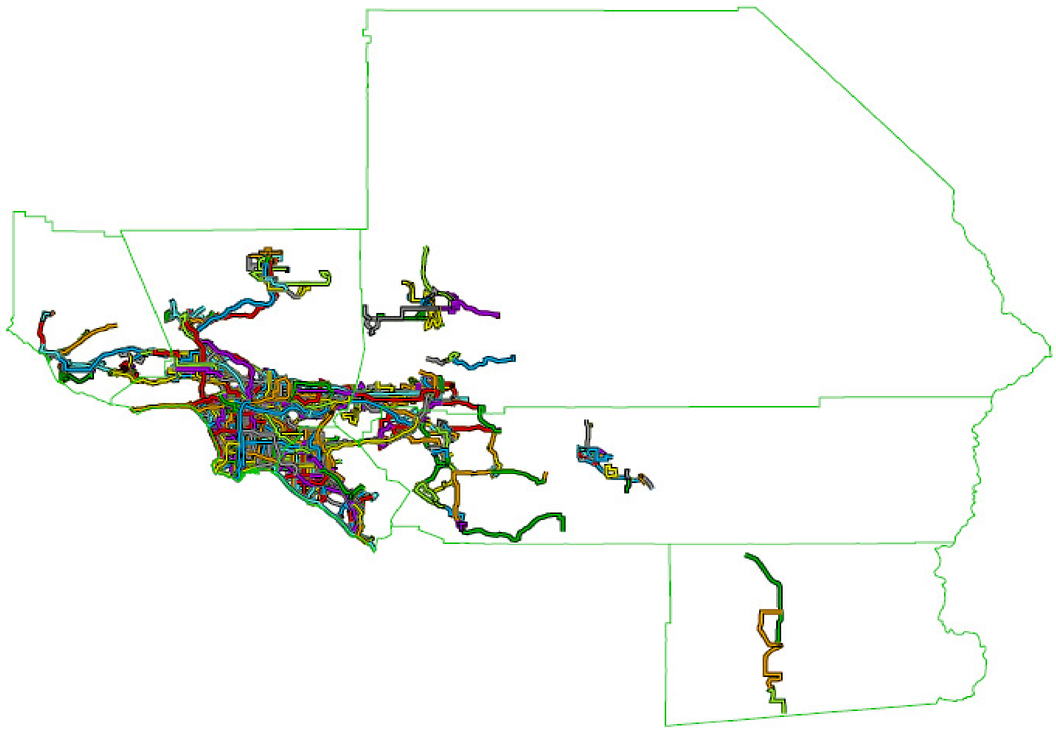


FIGURE 2 SCAG transit network.

METHODOLOGY FOR COMPUTING ACCESSIBILITY AND SAMPLE MAPS

Methodology

Figure 3 illustrates the structure of accessibility indicators developed in this study at the block level. As shown in red, three sets of indicators are constructed -- number of employees by industry type and time of day, accessible roadway segment length by functional classification, and number of transit stops within a certain traveling time. The first two sets are based on the highway network, while the third is based on the transit network. For all of these indicators, one first needs to define the time thresholds for use in computing accessibility. In the current research, we chose three time bands - 10 minutes, 20 minutes, and 50 minutes. The selection of these time bands was based on the trip length distributions from the 2001 post-census SCAG region household travel survey. According to this survey, 25 percent of trip lengths were less than or equal to 7 minutes, 50 percent of trip lengths were less than or equal to 25 minutes, and more than 75 percent of trip lengths were less than or equal to 50 minutes. So, we selected the 10-minute buffer to represent local accessibility, defined as the number of activity opportunities that can be reached within 10 minutes. At the other extreme, we selected a 50-minute buffer to represent regional accessibility, defined as the number of activity opportunities that can be reached within 50 minutes. The 20-minute buffer was added for completeness and to provide indicators for activity opportunity between the local and regional scales. This threshold is also chosen because research elsewhere claims that a desired ideal commute time is somewhere between 15 and 19 minutes (*9*).

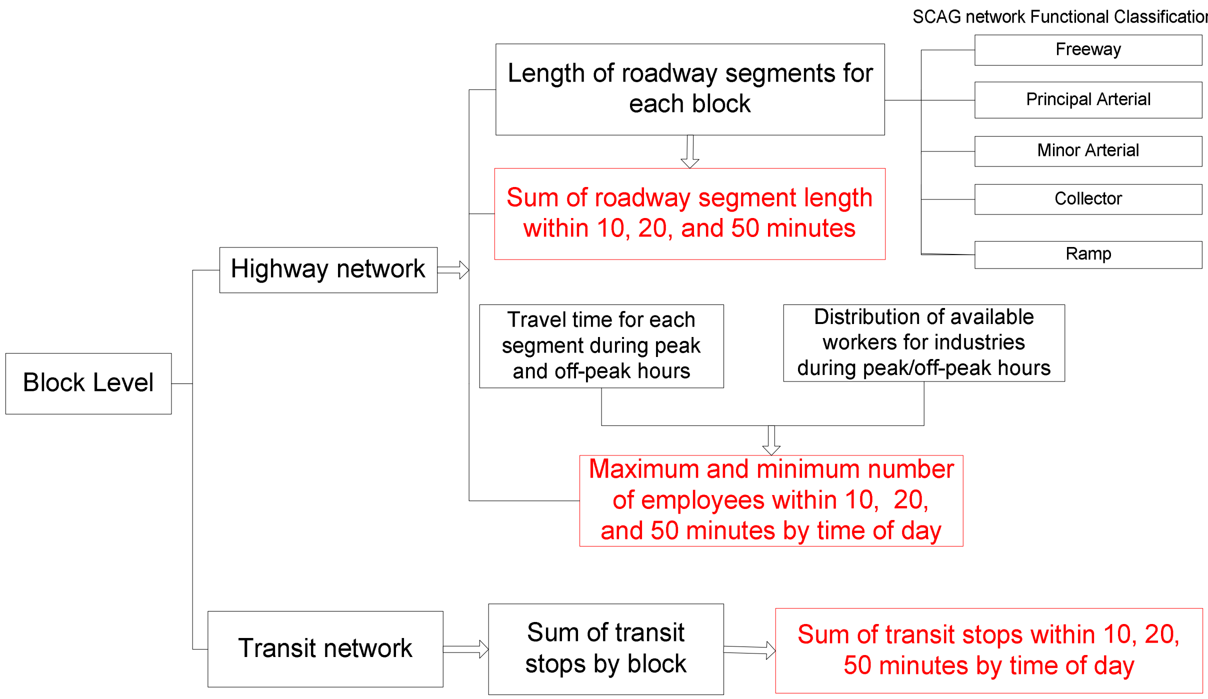


FIGURE 3 Establishment of accessibility indicators at block level.

In all the computations of the time buffers just discussed, the highway network time is used. However, the highway network time varies by time of day. This may result in different buffer areas for the same block at different times of the day, implying different numbers of activity opportunities for the block over the course of the 24-hour period. To account for the travel time variance, travel times between blocks for different time periods in a day are needed. As mentioned earlier, the current SCAG four-step model provides travel speed and time for each roadway segment for four time periods, AM peak (6 AM to 9 AM), PM peak (3 PM to 7 PM), Midday off-peak hours (9 AM to 3 PM), and Nighttime off-peak hours (7 PM to 6 AM). This allows the calculation of shortest path travel time between blocks for each of these four different periods in a day. But, given the large number of blocks within the SCAG region, it is almost impossible to directly use either GIS tools or the built-in tools provided by existing GIS software to create the shortest paths between block centroids. An alternative approach is to identify the nearest network node for the block centroids, assuming that these nodes represent the block centroid. By applying the travel speed of roadway links, the travel time between these nodes (proxies now for block centroids) are computed using the shortest path tool in TransCAD ®. By doing so, the travel time matrices between blocks are created for the four time periods. The SCAG region consists of 203,191 blocks. Accordingly, each time period has a 203,191*203,191 shortest travel time matrix. Table 2 lists the block-to-block highway network travel time for a few randomly selected blocks. The rows represent origin blocks and the columns represent destination blocks. For example, the travel time from block 1 to block 10 is 22.6 minutes, while the travel time from block 10 to block 1 is 19.6 minutes. The 10, 20, and 50-minute buffer areas for each block can be generated on the basis of these travel time matrices. The accessibility indicators can be subsequently created by counting the related block characteristics within the

TABLE 2 Sample Block Travel Time Matrix (Minutes)

	Destination											
Origin	1	2	3	4	5	6	7	8	9	10	11	12
1	0.0	1.3	3.7	10.9	13.0	20.1	19.8	19.8	22.4	22.6	19.6	21.1
2	1.3	0.0	2.4	9.6	11.6	21.4	21.1	21.1	23.7	23.9	20.9	22.4
3	3.7	2.4	0.0	7.3	9.3	23.8	23.5	23.5	26.1	26.3	23.2	24.8
4	10.9	9.6	7.3	0.0	2.0	31.0	30.7	30.8	33.4	33.5	30.5	32.0
5	13.0	11.6	9.3	2.0	0.0	33.0	32.7	32.8	35.4	35.5	32.5	34.0
6	19.1	20.4	22.7	30.0	32.0	0.0	8.7	8.8	11.4	11.5	8.5	10.0
7	22.4	23.7	26.1	33.3	35.4	3.3	0.0	3.1	2.6	2.8	11.7	4.3
8	19.6	20.9	23.3	30.5	32.6	0.5	9.3	0.0	11.9	12.1	9.0	10.6
9	19.8	21.1	23.4	30.7	32.7	0.7	0.5	0.4	0.0	0.2	9.1	1.7
10	19.6	20.9	23.3	30.5	32.5	0.5	0.3	0.3	2.9	0.0	8.9	1.5
11	19.8	21.1	23.5	30.8	32.8	0.8	0.4	0.5	3.1	3.3	0.0	1.7
12	21.0	22.3	24.7	32.0	34.0	2.0	1.7	1.6	4.4	4.6	10.4	0.0

buffer area, including the number of employees by industry type, amount of roadway length by functional classification, and the number of transit stops. For the roadway length by functional classification and transit stop indices, it is reasonable to assume that, once the buffer zone is defined, the roadway lengths and number of transit stops will not be a function of time of day. Thus, variations in these indicators by time of day are purely because of change in the buffer areas by time of day. However, the accessibility indicator based on the number of employees by industry type should vary by time of day, even for a pre-defined buffer zone, because of the work schedules of employees. That is, there will be times when employees will not be at work, and this should be considered when computing the "number of "reachable" employees by industry type for use in constructing the accessibility indicator.

To estimate the percent of reachable employees by industry, we use the post-census SCAG region household travel survey that recorded the daily activity schedules for individual workers during a 24-hour period. In addition to daily activities, the survey also provides information associated with person, household, and activity locations. Specifically, for each respondent q that works, we have the arrival time at work (say t_{qa}) and departure time from work (say t_{qd}). Also, define a dummy variable δ_{qgh} that takes a value of one if individual q works in industry type g and county h, and zero otherwise. Now, consider a specific hour of the day k, and let T_s be the start time of this hour k, and let T_e be the end time of this hour k. Define another dummy variable α_{qk} that takes a value 1 if $t_{qs} \geq T_s$ and $t_{qe} \leq T_e$, and zero otherwise. Intuitively, α_{qk} equals one if the employee q is at the work place at the hour k and zero otherwise. From the travel survey, we also have a weight W_q for person q, which expands the individual so that the expanded sample across all surveyed individuals is representative of the population. With these notational preliminaries, an estimate of the number of reachable employees in industry type g at county h at time k (A_{ghk}) is as follows:

$$A_{ghk} = \sum_q \delta_{qgh} \alpha_{qk} W_q$$

For application purposes, it is convenient to translate the total number of reachable workers in industry *g* at county *h* at time *k* into a percentage of reachable workers in industry *g* and county *h*:

$$P_{ghk} = \frac{A_{qhk}}{\sum_{q} \delta_{qgh} W_q}.$$

Table 3 shows an example of the reachable number of the retail trade workers in Los Angeles County by time of day. The above percentage can be computed for each time of day. However, the buffer zones which are a function of network times vary only by the four time periods available from the SCAG model. So, we also compute measures of the percentage of number of reachable employees for each of these four periods. Since there are substantial variations in the P_{ghk} values within the four time periods (for example, this value varies between 17.65% for the 6-7 am period to 42.14% for the 8-9 am period within the AM peak period), we develop minimum and maximum percentages of reachable workers for each industry type *g*, county *h*, and time period *k*. For example, based on the percentages in the main part of Table 3, the bottom portion of the Table 3 provides the minimum and maximum percentages of reachable retail trade employees in LA County by each time period.

The minimum and maximum percentages by industry type, county, and time period are applied to all blocks belonging to the county. Since the total employment within each block by industry type is available based on the discussion in the section entitled "Employment Data from CTPP and D&B", one can immediately compute the number of reachable employees by industry type, block, and time period. Finally, the accessibility measure based on the number of reachable employees at any time *k* for any block is simply equal to the sum of reachable employees at that time *k* across all blocks that are within the buffer area of the block at that time *k*. Considering the large number of blocks within the SCAG region, a C++ program was developed to complete the aggregation task. The next section presents sample maps of the accessibility indicator corresponding to the number of reachable employees.

TABLE 3 Worker Reachability for Retail Trade in Los Angeles County (*g*=retail trade, *h*=LA county)

Time period	Time of Day *(k)*	Number of Reachable Workers (A_{ghk})	Percentage of Reachable Workers (P_{ghkt})
AM Peak	6-7 am	50254.27	17.65%
	7-8 am	81503.92	28.63%
	8-9 am	119973.63	42.14%
Midday	9-10 am	137478.69	48.29%
	10-11 am	143530.49	50.41%
	11 am-12 Noon	150424.52	52.83%
	12-1 pm	146426.29	51.43%
	1-2 pm	143776.82	50.50%
	2-3 pm	133204.27	46.79%
PM peak	3-4 pm	124300.59	43.66%
	4-5 pm	105383.12	37.01%
	5-6 pm	66120.22	23.22%
	6-7 pm	49245.79	17.30%
Night Time	7-8 pm	37855.78	13.30%
	8-9 pm	31819.52	11.18%
	9-10 pm	20909.54	7.34%
	10-11 pm	19621.49	6.89%
	11 pm-12 Mid	17077.40	6.00%
	12-1am	18990.41	6.67%
	1-2 am	17996.88	6.32%
	2-3 am	9498.92	3.34%
	3-4 am	20463.11	7.19%
	4-5 am	22541.33	7.92%
	5-6 am	33185.59	11.66%

Minimum and Maximum Percentage of Workers from Retail Trade in LA County

Time of Day	Minimum Percentage of Reachable Workers	Maximum Percentage of Reachable Workers
AM peak (6:00 AM - 9:00 AM)	17.65%	42.14%
Midday (9:00 AM - 3:00 PM)	46.79%	52.83%
PM peak (3:00 PM - 7:00 PM)	17.30%	43.66%
Night time (7:00 PM - 6:00 AM)	3.34%	13.30%

Examples of Accessibility Maps

Retail Industry Figure 4 presents the maximum number of reachable retail employees within 10 minutes during the four time periods in the Santa Monica area of Los Angeles County. The reader will note the expansion of the dark green area as one moves from the AM peak to the Midday period, and the subsequent shrinkage in the dark green area during the PM peak and night time periods. The variation in the percentage of the reachable employees as well as in travel time lead to the time-of-day changes in accessibility.

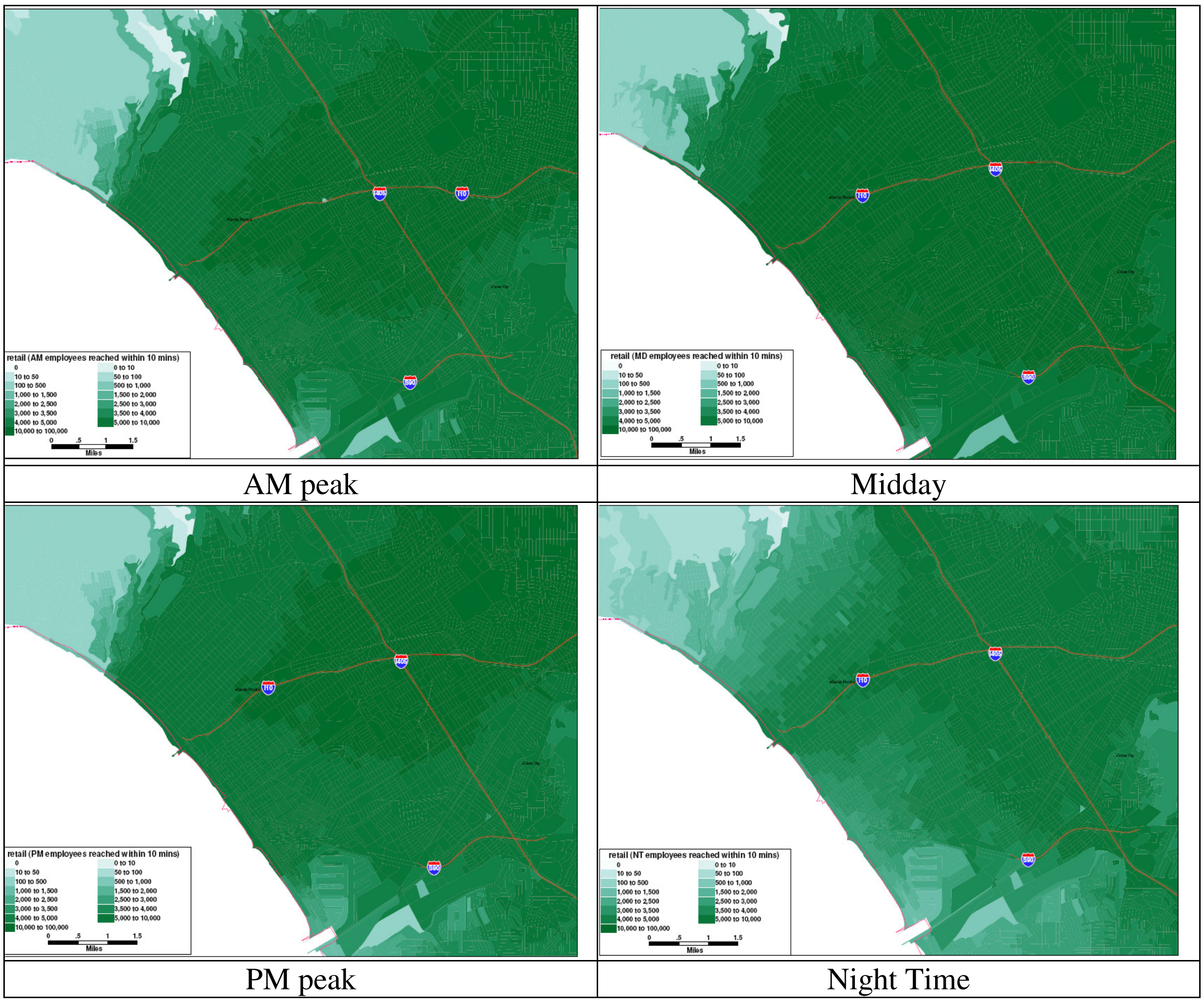


FIGURE 4 Maximum number of reachable retail employees for a 10-minute buffer by time of day in Santa Monica.

Education and Health Industry As mentioned earlier, the combined education and health employment in the CTPP data was separated into two groups with the help of the D&B data. The maximum number of reachable education employees within 10 minutes during each of the four time periods in the Santa Monica area of Los Angeles County is presented in Figure 5. Figure 6 presents the corresponding map for the health industry. Both sets of graphs exhibit similar change trends as the retail industry, which again demonstrates that the accessibility indicators can capture activity opportunity changes during the day. The AM peak and Midday periods have the highest accessibility based on the number of reachable employees. As time progresses, the number of reachable employees decreases and reaches the lowest point during the night time. There are, however, also differences between Figures 5 and 6. First, the accessibility map for the health industry is much darker than the accessibility map for the education industry for all time periods, indicating the higher number of reachable health industry employees relative to the education industry. Second, the fading of the dark green as the day progresses is decidedly much lower for the health industry than for the education industry. This is because a non-significant fraction of health care workers are needed at their work place round the clock. Clearly, the separation of the two industry types done in this research improves accessibility analysis and should strengthen its use in activity scheduling.

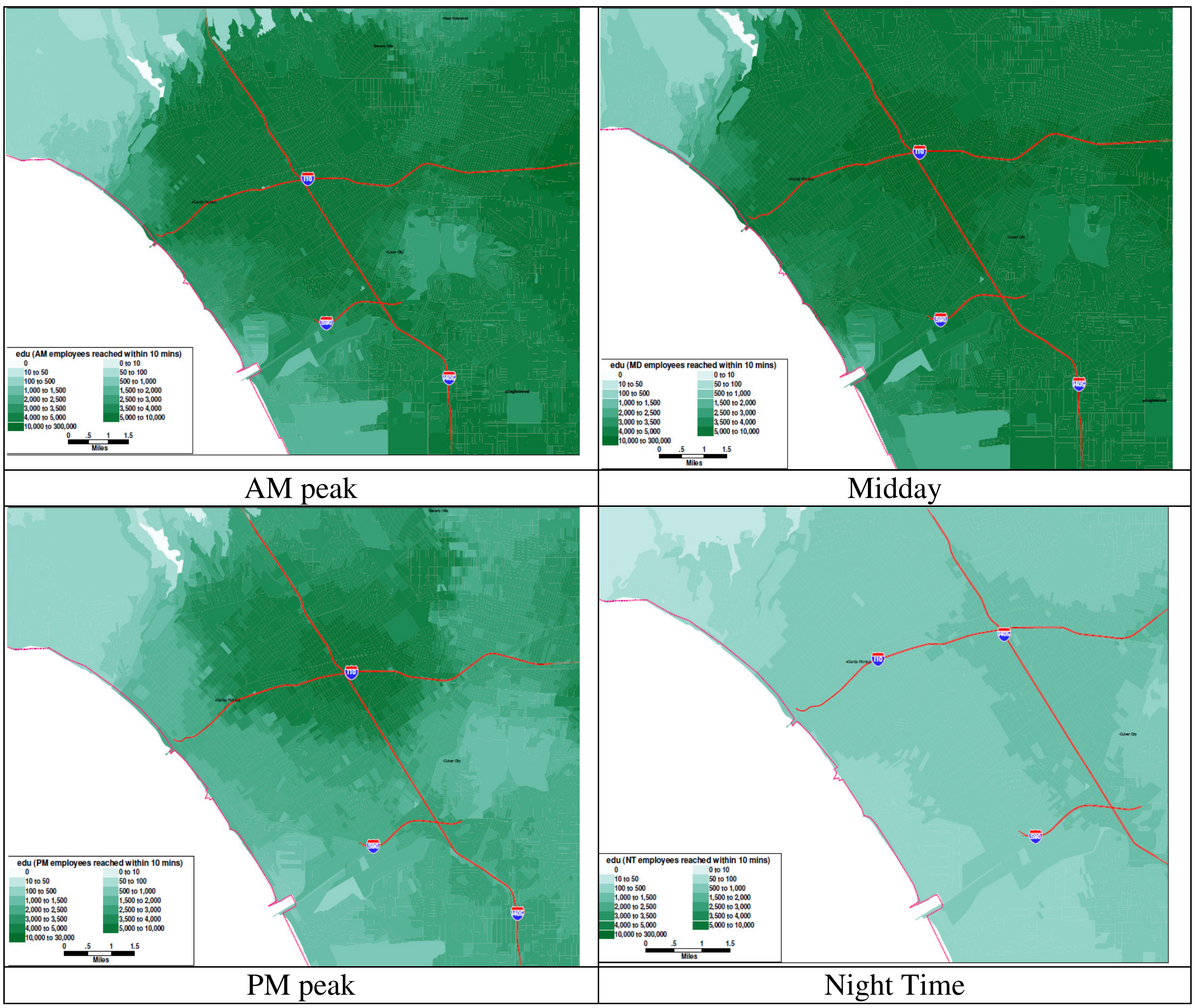


FIGURE 5 Maximum number of reachable education employees within 10 minute buffer by time of day in Santa Monica.

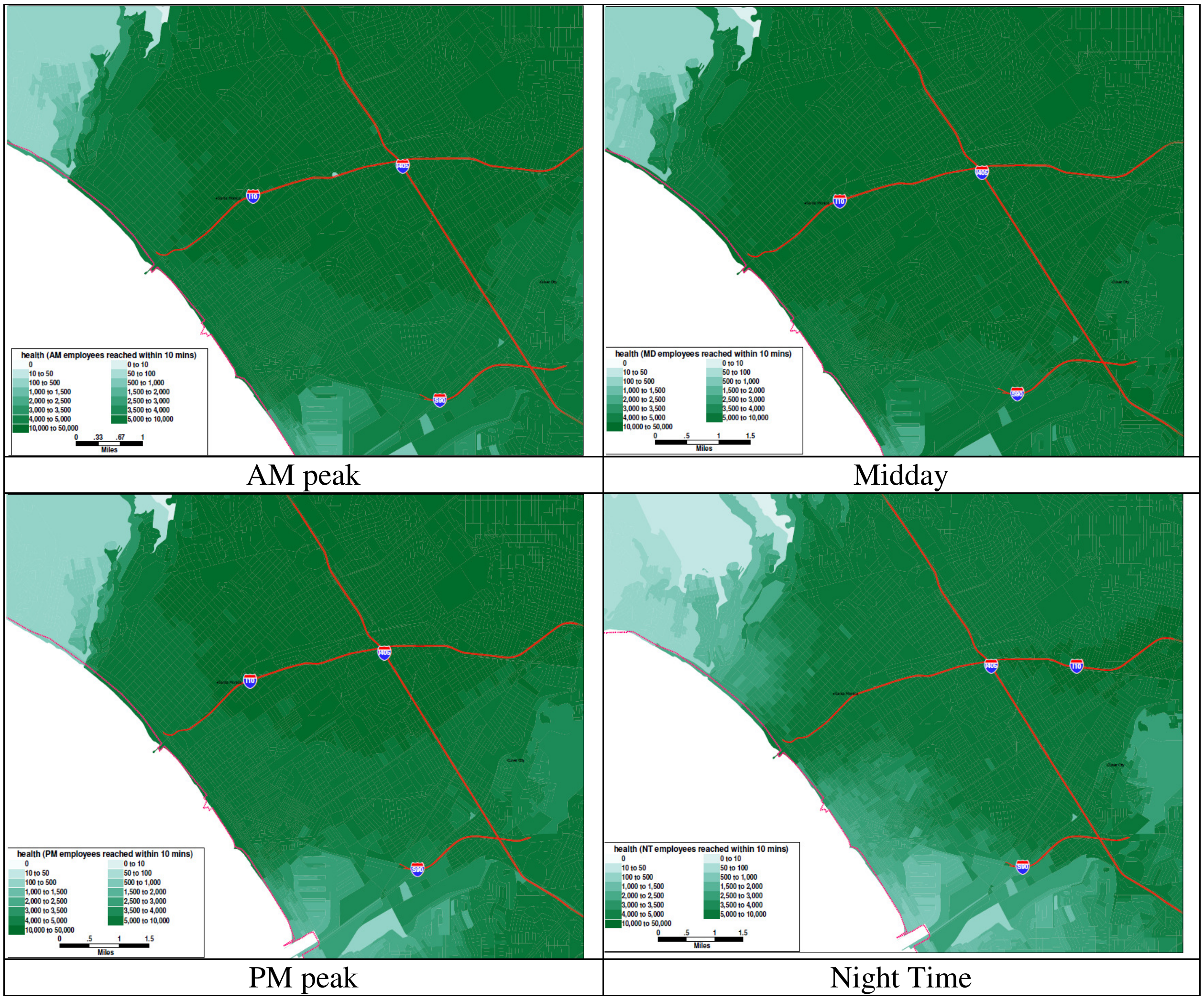
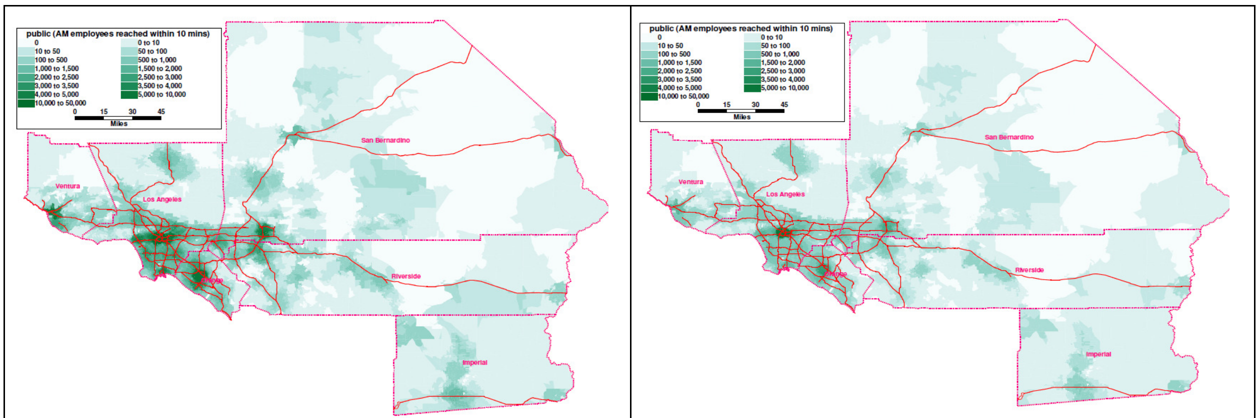


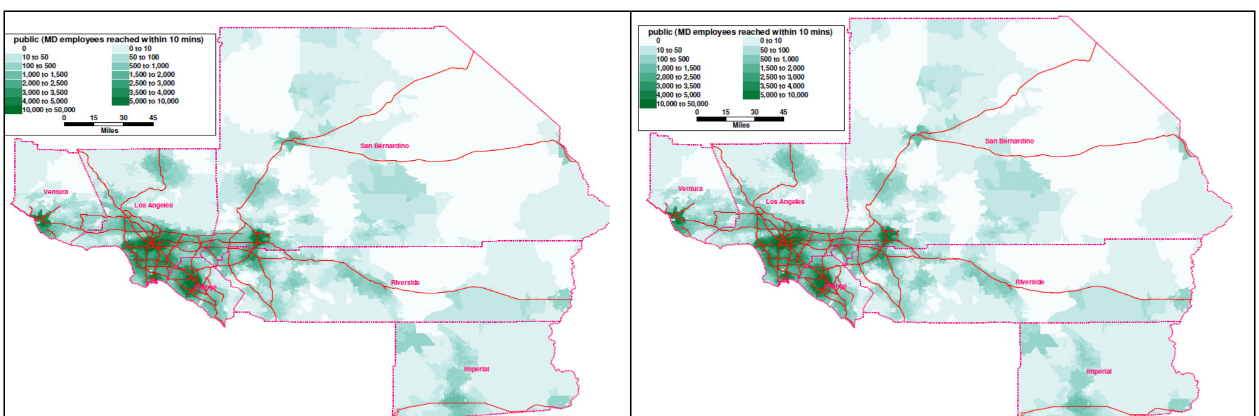
FIGURE 6 Maximum number of reachable health employees within 10 minute buffer by time of day in Santa Monica.

Public Services Figures 7a to 7d compare the maximum and minimum number of reachable public service employees for the entire SCAG region, using a regional level buffer of 10 minutes. In each figure, the map on the left represents the case of maximum number of reachable employees, while the map on the right represents the case of minimum number of reachable employees. The usual darkening of the green from the AM peak to the mid-day period, and the subsequent fading of the green, is discernible as one goes down the figures column-wise. In each row, and particularly for the case of the AM peak period and the PM peak period, there is a clear lightening of the green as one goes from the left to the right. This indicates that the maximum number of reachable public service employees for the blocks are significantly higher than the minimum number of reachable employees during the AM and PM peaks periods. Thus, by employing both maximum and minimum numbers of reachable employees, the accessibility indicators reflect the fluctuation within the AM and PM peak due to work schedules. Although the row-wise comparisons for the midday and nighttime periods shown in Figures 7b and 7d, respectively, are not as significant as for the AM and PM peak periods, there is still a detectable difference between the accessibility indicators based on the maximum and minimum reachable employees.



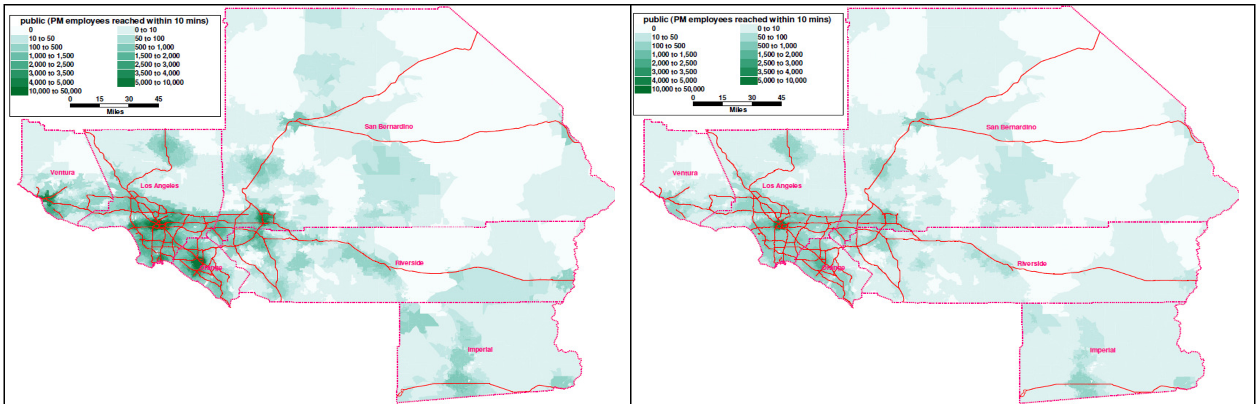
Maximum Available employees	Minimum Available employees

FIGURE 7a Comparison of maximum and minimum public service employees (AM peak).



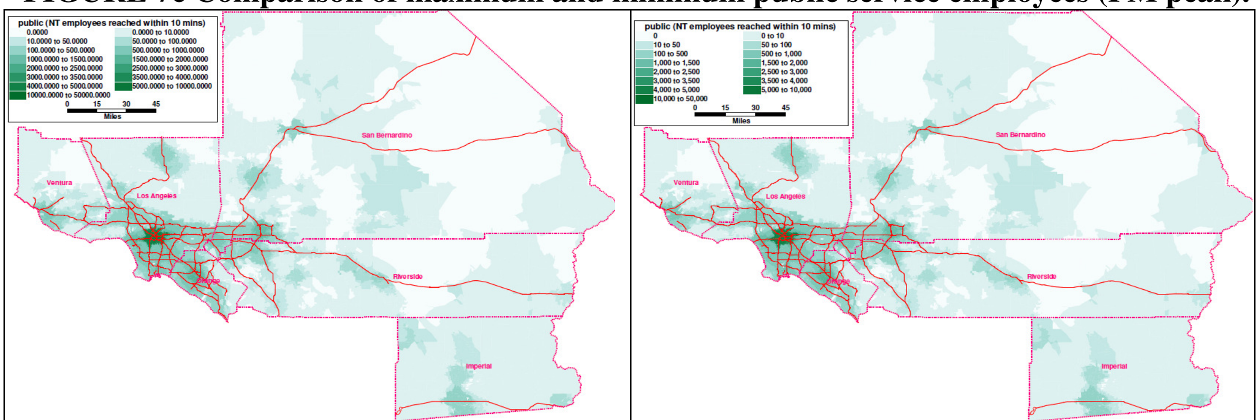
Maximum Available employees	Minimum Available employees

FIGURE 7b Comparison of maximum and minimum public service employees (Midday).



Maximum Available employees | Minimum Available employees

FIGURE 7c Comparison of maximum and minimum public service employees (PM peak).



Maximum Available employees | Minimum Available employees

FIGURE 7d Comparison of maximum and minimum public service employees (Nighttime).

SUMMARY AND CONCLUSIONS

This study presents a GIS-based methodology to generate block-level accessibility measures that incorporate both spatial and temporal dimensions. These accessibility measures will be used to support the activity-based SCAG regional planning model. Three databases were used in the effort, including geo-coded block group and block data, SCAG roadway and transit network, and the Census Transportation Planning product (CTPP) and Dun & Bradstreet (D&B) data. In short, the method consisted of seven steps:

a. Adjust the employment data in CTPP by merging with the D&B database
b. Supplement the current highway network embedded in the SCAG four-step model using Tele Atlas 2000, to enable adequate network density for block level accessibility analysis
c. Estimate a block-group level relationship between employment and independent variables for 15 industry types, including area, population, and roadway segment lengths as the independent variables.
d. Perform spatial disaggregation to distribute the block group employment data down to the block level using the estimated models in step b
e. For each of the four time periods, locate the 10, 20, and 50-minute buffer areas for each block within the SCAG region using the link travel speeds from the current SCAG four-step model

f. Obtain the maximum and minimum percentage of reachable workers during each of the four time periods, using the post-census SCAG region household travel survey
g. Compute the accessibility measures by counting the reachable employees by industry type, accessible roadway segment length by functional classification, and transit stops within the three buffer thresholds for the four time periods.

Given the block group level census data, this paper proposes a new approach to distribute the employees to each block according to block characteristics. In addition, the travel speed of the network links, and the reachable employees by time of day, are explicitly considered to capture temporal variations in the accessibility indicators over time. This enhanced sensitivity of the accessibility indicators should be beneficial in explaining and predicting travel behavior. As importantly, this study has demonstrated the feasibility of developing GIS-based block-level regional and local accessibility indicators even for the vast SCAG planning region.

Of course, the study is not without its limitations. First, due to the absence of the bicycle lanes and sidewalks from the network database, all the accessibility measures generated here are based on motorized vehicle speed. Therefore, non-motorized accessibility measures are missing from this study. Given legislation on reducing green house gas emissions, increasing non-motorized trips is one of the potential solutions. In a future study, we will also include non-motorized accessibility indicators. Second, the accessibility indicators use the traveling speed for the four time periods from the SCAG four-step model. Correspondingly, the number of reachable employees for the same four periods are generated. However, the number of reachable employees varies from hour to hour. The introduction of maximum and minimum number of reachable employees during each of the four broad time periods attempts to recognize the variation within each broad time period, but is not entirely satisfactory. In the future, we expect to develop estimates of travel speed for each hour in a day and then to better address the variation in reachable employees.

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