Geolocating Activities to Business Establishment Locations Using Time-Dependent Activity Assignment for Travel Demand Modeling

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ABSTRACT
Activity geolocation is the identification of the real-world geographic location of an activity. It is closely related to destination choice and stop location choice in activity-based approaches in travel demand forecasting models. In this paper, a new activity assignment approach is proposed that considers as input the activities predicted for each person in an activity based microsimulation model system called SimAGENT and an inventory of business establishments provided by a commercially available database. This approach produces geolocated activities (e.g., eating out at a restaurant, going shopping) at locations of a subset of real-world business establishments enabling small area studies and the micro-assignment of greenhouse gas assignment at fine resolution to perform impact analysis. This method is implemented in TRansportation ANalysis SIMulation System (TRANSIMS) and compared to a naive approach of assigning activities to random locations within traffic analysis zones of SimAGENT.

Keywords: Activity Assignment, accessibility, Activity Based model, Travel Demand Model, TRANSIMS
INTRODUCTION

Over the last decades, traffic demand studies relied mostly on traditional aggregated models, including the four step model, which uses a central point (called centroid) of each traffic analysis zone (TAZs) as the spatial resolution of activity destinations. In recent years, however, activity-based travel demand models have gradually gained acceptance over the conventional four step travel demand models in the U.S. for large metropolitan areas(1). In the past few years, many activity-based models have been implemented (1,2,3,4,5,6). Many applications of activity-based models continue to rely on zones as the spatial level of detail, and to rely on four or five broad time periods of the day as the temporal level of detail(1). The activity-based model system in Portland by Bradley et al. (1998) (3), San Francisco by Bradley et al. (2001) (4), New York by Vosha et al. (2002) (5), and Sacramento by Bowman et al. (2006) (6) are four examples. Some case studies use disaggregated activity-based models like TRansportation ANalysis SIMulation System (TRANSIMS) or Multi-Agent Transport Simulation (MATSim) for travel demand modeling and microsimulation. In TRANSIMS, activities at zonal level are disaggregated to self-generated roadside activity locations that represent locations of households and businesses (7,8), while roadway nodes and links in MATSim are used for generating activity chains for both activities and origin-destination matrices (1,9,10). However, the actual household/business establishment locations are not fully expressed from the models above.

Finer resolutions are now implemented to capture accessibility by different modes and it is also desirable to develop methods that can geolocate activities to actual geographical locations. By reallocating activity destinations to business establishment locations, the activities and travel patterns can be positioned more accurately and local road traffic modeled accordingly. In this way, we can move to the next stage of using activity-based models for small area studies, interfacing them with regional land use plans at the parcel level and also studying the environmental impacts including Greenhouse Gas (GHG) emissions at the individual business location. A robust method of geolocating activities to individual businesses is also helpful for small area traffic impact studies.

Geolocation of activities can be divided into two major groups. The first one is the home geolocation, a process that identifies the parcel of a land and a housing unit in which a simulated household lives. Ideally, one can match household characteristics to housing unit characteristics. Since most activity-based model systems synthetically generate households within traffic analysis zones (derived from US Census blocks and block groups), a conditional probabilistic assignment approach is currently being tested in this context for home geolocation. Second, out of home activity geolocation is a process that uses as source information such as activity type generated for each individual, the information about joint activities with other members, and the destination at which an activity is situated based on a synthetic schedule simulator. And then, each activity is matched to a real world location (business establishment) for which we have data about the type and size of each business as well as the longitude and latitude (and the address) of the business establishment.

In this paper, geolocating activities are processed and implemented with TRANSIMS. Based on the generated destination TAZ and travel purpose of an activity, we identify the actual business locations within the TAZ and select one location whose type matches the travel purpose as the destination. With the selected business location, we assign the activity to the TRANSIMS activity location which is the nearest to the selected business location. The information about the “desirability” of each location for different periods is also included in this paper by making use of previously derived time of day profiles mimicking the capacity of each activity location. In
this paper, we define desirability as the attractiveness of a place based on availability of employees by time of day. In this way we take advantage of two types of temporal information that are: a) the time of day when the activity is predicted to take place; and b) the time of day that an activity location is available for activities. This method partially fills the gap in the literature of disaggregate approaches to travel demand forecasting by creating an activity assignment location method at a finer resolution. This method also has benefits associated with traffic and environmental impact studies in small areas.

The remainder of the paper is organized as follows. In the next section we provide an overview of the data used for activity geolocation. This is followed by the method and the results and a comparison with random assignment of locations. The paper ends with a brief summary and conclusions for next steps.

**DATA USED**

This study makes use of multiple data sources to achieve the proposed new activity assignment method. The four major data sources include Southern California Association of Governments (SCAG) roadway and transit network, business employment and accessibility information by time of day and daily activity schedule from SimAGENT. These data sources are briefly described in detail as follows.

**SCAG Roadway and Transit Network**

The SCAG network is extracted from the SCAG four-step model including geo-referenced freeways and major roadways in year 2000. Along with the roadway network, a transit network is also extracted from the four-step-model. The transit data include all the transit stops, routes, and headways. The entire network is then processed and converted into TRANSIMS input data. The TRANSIMS network building program uses basic link and node information to synthesize its own network and the data fields. The network files contain a series of components like node, link, zone, the number and location of turn pockets, the parking locations and activity locations and process links that connect the two, the lane connections at intersections, etc. The activity locations (ALs) in TRANSIMS are self-generated roadside points where individual activities start and end. In this paper, TRANSIMS ALs and business establishment locations are connected for activity assignment described later in the methodology section. The program also removes unnecessary nodes, updates the shape points, and converts external station zone connectors to roadways. Validations and calibrations for all the generated network components have been addressed after the network building process and used in activity assignment procedure (11). The TRANSIMS network is shown in Figure 1 and includes 49,239 links, 31,039 nodes and 4,192 TAZs. TRANSIMS also generates 287,464 activity locations in the program (12).

**Time of Day Business Accessibility**

Business accessibility data are the percentages of available employees that can be reached by each individual at different time periods in a day. The accessibility indicators as defined by Chen et al. (2011) are computed for the 15 industry types based on North American Industry Classification System (NAICS) as retail, arts, health, education, and so forth (13). Figure 2 shows the percentage of available employees in fifteen different industry types in six counties within SCAG region, the X-axis represents the 24 hours of a day while Y-axis is the percentage of employees available.
Business Employment and Establishment Location

Business employment data are used to obtain locations with business information in SCAG. The data are derived from National establishment time series (NETS) database. The NETS data is a compilation of Dun and Bradstreet (D&B) archival establishment data into a time-series database (14). The D&B data contains more than 1 million business records for SCAG area. This database consists of information on individual business establishments that includes geo-referenced business location, employment size, and industry type as defined by NAICS. Using the longitude and latitude of each employment record, Business Location (BL) points with various business related characteristics are generated. For this study we use the 2003 employment data because the simulation of activities was done for the year 2003 in this application. A total of 1,015,842 locations are included in SCAG area. Table 1 is a small sample from business location data.

Daily Travel Activity

The daily travel activities for each household and person in SCAG are synthetically simulated and provided by the newly developed Comprehensive Econometric Microsimulator of Daily Activity-travel Patterns (CEMDAP) version used in SimAGENT (15,16). The CEMDAP generated activities are converted to TRANSIMS activity format before the geolocation assignment and they are points adjacent to the available network. Before the activity assignment, the characteristics of household activities need to be studied first. A person’s daily activities are highly correlated. For example, a person walking to a restaurant at noon from his/her working place will return to the location where he/she works. In the simulation people go back home after finishing all their activities. Joint activities also exist among the household members. Therefore, activity assignments discussed later are processed for each household. Known from the activity data, all the activities start from home, one TRANSIMS AL in the origin zone is selected as the home activity of every agent in a household as home location. For the rest of the activities, whether to assign to new location or to a previous one in a sequence can be decided based on the scheduled destination zone, the travel mode and the usage of vehicle. For the last activity of each person, if the destination zone of the last activity is the same to the home location zone, the last activity is treated as a back home activity and the location is set to the home location.

SimAGENT provides a list of each person’s activity for a 24-hour period along a continuous time axis (in implementation for every minute of a day). The activity data is generated based on the household travel survey data in 2003, which include 69 travel related characteristics such as travel time, duration, origin, destination, purpose, travel modes, etc. A total number of 51,212,733 out-of-home activities for nearly 18 million people for the entire SCAG region are generated and restructured to become the input activities to TRANSIMS. For each person, it requires adding a home-based activity from the start of the day to the time when the first actual activity begins.

An example of the spatial distribution of the TRANSIMS AL and BL on the network is shown in Figure 3. It is apparent that the number of BLs in D&B database are many more than the generated ALs by TRANSIMS. This is because TRANSIMS uses a simplified network and generates activity points internally along freeways and major roads while BLs are the real world points along the local roads. On the map of Figure 3 we show the roadways with the TRANSIMS generated AL points and the BLs in green color.
### TABLE 1 Sample of Business Locations

<table>
<thead>
<tr>
<th>ID</th>
<th>ADDRESS</th>
<th>X_COORD</th>
<th>Y_COORD</th>
<th>CITY</th>
<th>STATE</th>
<th>ZIPCODE</th>
<th>ZIP4</th>
<th>LEVELCODE</th>
<th>EMP03</th>
<th>EMPHERE</th>
<th>SIC2</th>
<th>SIC3</th>
<th>SIC30</th>
<th>INDUSTRY</th>
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<td>33.6343</td>
<td>MARGARITA</td>
<td>CA</td>
<td>92660</td>
<td>1336</td>
<td>Z</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carpet and upholstery cleaning</td>
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<tr>
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<td>34.0857</td>
<td>ANGELES</td>
<td>CA</td>
<td>90040</td>
<td>5701</td>
<td>D</td>
<td>3</td>
<td>47</td>
<td>47</td>
<td>4724</td>
<td>Travel agency</td>
<td></td>
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<tr>
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<td>33.668</td>
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<td>CA</td>
<td>92668</td>
<td>2120</td>
<td>D</td>
<td>2</td>
<td>2</td>
<td>50</td>
<td>50</td>
<td>5060</td>
<td>Equipment, nec</td>
</tr>
<tr>
<td>1015470</td>
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<td>-117.744</td>
<td>33.5983</td>
<td>RANCHO SANTA MARGRTA</td>
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<td>92668</td>
<td>1805</td>
<td>D</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>7810</td>
<td>Landscape services</td>
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<tr>
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<td>34.0712</td>
<td>RANCHO SANTA MARGRTA</td>
<td>CA</td>
<td>92408</td>
<td>2838</td>
<td>D</td>
<td>40</td>
<td>10</td>
<td>87</td>
<td>87</td>
<td>8742</td>
<td>Mailing services</td>
</tr>
<tr>
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<td>35.8817</td>
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<td>D</td>
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<td>10</td>
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<td>93065</td>
<td>4045</td>
<td>D</td>
<td>4</td>
<td>4</td>
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<td>87</td>
<td>8742</td>
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<td>90210</td>
<td>4622</td>
<td>D</td>
<td>2</td>
<td>2</td>
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<td>62</td>
<td>6210</td>
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<td>CA</td>
<td>91404</td>
<td>3532</td>
<td>D</td>
<td>2</td>
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<td>87</td>
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</tr>
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<td>33.8000</td>
<td>GARDENIA</td>
<td>CA</td>
<td>90493</td>
<td>2500</td>
<td>D</td>
<td>5</td>
<td>23</td>
<td>51</td>
<td>51</td>
<td>5140</td>
<td>Mailing services</td>
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<td>34.2440</td>
<td>ELLSWORTH</td>
<td>CA</td>
<td>91211</td>
<td>5608</td>
<td>D</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>1710</td>
<td>Mailing services</td>
</tr>
<tr>
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<td>34.5300</td>
<td>HUBA TREE</td>
<td>CA</td>
<td>92232</td>
<td>2523</td>
<td>D</td>
<td>14</td>
<td>14</td>
<td>12</td>
<td>12</td>
<td>1210</td>
<td>Mailing services</td>
</tr>
</tbody>
</table>

**FIGURE 1:** Network of SCAG in TRANSIMS
FIGURE 2 Examples of time of day availability for different business types
FIGURE 3 An example of SimAGENT-TRANSIMS activity locations (red dots) and real world business locations (green dots)

METHODOLOGY
To match the daily SimAGENT activities with businesses in both space and time we follow the flowchart of Figure 4. With the destination TAZ and the purpose of every activity from SimAGENT, a collection of ALs within the TAZ and the BLs by business type matching to the activity purpose are both selected. Then, employee availability is used to match workers to locations by industry type as explained below.

Consider a zone \(i\) within the SCAG region (the region contains 4192 zones, \(i=1,2,...,4192\)). The total number of available locations in zone \(i\) at time period \(T\) is \(O_i(T)\). The universe of all available locations at time \(T\) for the entire SCAG region is:

\[
O(T) = \sum_{i=1}^{4192} O_i(T)
\]  

To reflect the time of day change in availability of activity opportunities we compute the number of available locations in zone \(i\) in period \(T\). In equations, the number of available BLs in zone \(i\) at period \(T\) is:

\[
O_i(T) = \left\{ \sum_{j=1}^{n_i} I \left[ E_{ijk}, P_{ijk}(T) \right] \right\} I \left[ E_{ijk}, P_{ijk}(T) \right] = \begin{cases} 1, & E_{ijk} \times P_{ijk}(T) \geq 1 \\ 0, & E_{ijk} \times P_{ijk}(T) < 1 \end{cases}
\]  

Where, \(n_i\) – number of business locations in zone \(i\)
\(E_{ijk}\) – employment size of the business location \(j\) in zone \(i\) with the activity type of \(k\)
\(P_{ijk}(T)\) – percentage of available workers of business location \(j\) in zone \(i\) with business type of \(k\) by the function of time \(T\)

\(I \left[ E_{ijk}, P_{ijk}(T) \right]\) – indicator function of \(E_{ijk}\) and \(P_{ijk}(T)\)
In this study, a county wide percentage of available workers by time of day \( T \) is applied to each individual business location \( j \) which belong to zone \( i \) for business type \( k \). Let’s take zone “584” as an example. The total number of available business locations is 405. These 405 business locations are connected to its nearest AL and categorized in 15 different industry types. The business type of BL “135293” in Zone “584” is “Construction” in Los Angeles County. And its employment size is “17” which is \( E_{ijk} \) in equation (2). We can then search the business accessibility matrices of LA county to find the correspondent percentages of “Construction” for a whole day. For example, at 10:00 AM, the percentage is 52.03% while at 5:00 PM it is 11.53%.

And the available workers can be calculated in location “135279”. The available workers are 8 (17*52.03%) at 10:00 and 1 (17*11.53%) at 17:00 which are used to compute \( E_{ijk} \times P_{ijk}(T) \) in equation (2). With this calculation, the available workers for the entire time of day can be obtained. When it comes to the activity assignment, from the ActivityType_IndustrialType cross matrices, the activity can be assigned to the AL which connected to the BL “135293” with an activity type of “work”. However, more than one business locations belong to work activity. Therefore, only one location can be selected and assigned to the activity record from all the available BLs that correspond to the same activity ALs.

Closeness between ALs and BLs is decided according to the geographic coordinates of both locations, Euclidean distances are calculated for each BL to every ALs. Based on the distances, the AL with the shortest distance is selected as the correspondent location to BL. The BL and the selected AL are defined as a location pair. After that, a new location file that has both attributes from BL and AL is created from the pair. When activity is assigned to one business location, the specified AL in TRANSIMS can be located through the new location data. From Figure 5, the allocation of BLs to ALs is shown by the arrows.

The BL-AL connection approach mathematically is presented below. Let us define \( A \) is the set of TRANSIMS activity locations, \( B \) is the set of business locations; The \( \alpha'_n \) in set \( A' \) is the objective location where Euclidean distance \( d(\alpha_n, \beta_n) \) is the shortest \( d_{min} \) in the distance set \( D_n \). \( x_{\alpha_n}, x_{\beta_n}, y_{\alpha_n}, y_{\beta_n} \) are the latitude and longitude coordinates of \( \alpha_n \) and \( \beta_n \). The formulas are as follows:

\[
A' = \{\alpha'_1, \alpha'_2, \ldots, \alpha'_n\} \\
\alpha'_n = \{\alpha_{d_{min}} \mid d_{min} \in D_n\} \\
D_n = \{d(\alpha_1, \beta_n), d(\alpha_2, \beta_n)\ldots d(\alpha_n, \beta_n) \mid \alpha \in A, \beta \in B\} \\
d(\alpha_n, \beta_n) = \sqrt{(x_{\alpha_n} - x_{\beta_n})^2 + (y_{\alpha_n} - y_{\beta_n})^2}
\]

The BL-based geolocation assignment for activities is implemented in SimAGENT-TRANSIMS activity conversion. The first location of each person is treated as the home location, which is randomly chosen from the origin zone. The other locations where the actual activity happens are selected based on the proposed assignment approach. Figure 6 shows a distribution of the activity locations used in geolocation assignment in downtown Los Angeles area. Different colors of the points in the figure indicate different range of the times that have been geolocated. The red locations are assigned to more activities compared with the blue ones. The difference in the number of location distribution in each zone illustrates that the activity assignment is directional.

After location assignment for each person, activities are input to TRANSIMS for travel demand modeling. The daily activities are input into TRANSIMS router to generate the travel
plans. For the entire SCAG area, the travel plans that are generated for all the residents have 65,848,153 activity records and 1,360,348 goods movement trips in total. A parallelization scheme is carried out for travel demand modeling. The computation is done on a workstation with 12 CPU cores at 3.2GHZ and takes about 23 hours for the routing process. The plan and link summarize programs in TRANSIMS are used to compute the traffic volumes and speed on each network link. The typical TRANSIMS model follows in Figure 7.

The travel demand modeling for activity with BL-based assignment is conducted in TRANSIMS. It is an integrated system of travel forecasting models designed to give transportation planners more accurate and complete information on traffic impacts, congestion, and pollution. The travel demand model in TRANSIMS is an iterative process. The model flow is shown in Figure 7. The router reads individual activities and creates a series of travel paths called travel plans and they composed of travel mode, time period of travel, origin destination locations and a minimum impedance travel path between the origin and destination locations. Using Bureau of Public Roads (BPR) based traffic assignment function the software estimates link delays. In the initial step, based on the number of trips through each link, the PlanSum program summarizes all the travel plans. The LinkDelay program weights the new link delay data with the previous one and generates a new weighted link delay file for the current iteration. By comparing the travel plans and link delay, PlanSelect program creates a subset of households to re-route on the network and determines the optimized route for each selected person while creating new plans. The new plans will merge with the previous travel plans and start the next iteration. The iterations will stop and traffic results are computed when the result comes to some kind of User Equilibrium (UE).

The LinkSum program generates a variety of traffic related results, including link data files of volumes, speeds, travel times, volume/capacity ratios, travel time ratios, delay, average density, maximum density, average queue, maximum queue, and cycle failures summarized by time of day, report the links with the top 100 link volumes, lane volumes, period volumes, speed reductions, V/C ratios, travel time ratios, volume changes, or travel time changes and the link groups with total volumes greater than user specified values, report the distribution of travel time, V/C ratio, travel time change, and volume change by lane kilometer and time period. It can also calculate congestion duration-based measures by aggregating time periods with time ratios greater than a specified value and report various network performance statistics. In this paper, a link-by-link volume and average speed files are generated and compared between two methods of assigning activities to activity locations.
FIGURE 4 Assignment of activities with new business locations

FIGURE 5: Allocation of activity locations and business locations
FIGURE 6: Distribution of activity assigned of locations in downtown Los Angeles

FIGURE 7: Travel demand model in TRANSIMS
IMPLEMENTATION

The assignment and traffic demand modeling are carried out in SCAG region. Travel activity data generated from SimAGENT are used as input for travel demand modeling instead of TRANSIMS self-generated activities. Apart from travel activity data for passengers, goods movement trips from four-step-model are added for travel demand modeling as well. C# programs were developed to achieve all the data conversions and the BL based activity assignment. Due to the network limitation in TRANSIMS, when building the connections between AL and BL, AL may be connected to more than one business location. Although some ALs are connected with many BLs, it will not bring about major impacts on the current road network in traffic demand modeling because the differences only impacts roadways between AL to BL, which are excluded from TRANSIMS network. To better understand the geolocation assignment influence on travel demand modeling, a comparative study between business location based assignment and random activity location assignment is conducted for the SimAGENT-TRANSIMS application as well. For random location assignment, all activity locations are the same and treated equally. Locations are selected randomly from TRANSIMS activity locations without considering the business characteristics and time availability, thus leading to a relatively balanced assignment in each zone.

The link volumes and average speed per 15 minutes have been chosen for comparison and are analyzed and computed using TRANSIMS link summarize program. Figure 8 shows the comparison of volumes on one major local road, one freeway and the total network roadways while the comparison of average speed is shown in Figure 9. From Figure 8, the total traffic volume estimated for the entire study region for both the assignment models are not significantly different and the two volumes are almost identical. Comparing the volume and speed on local roadways and freeways, the differences of the two volumes on local road exist from morning until midnight. While on freeway, the volumes remain almost the same before 15:00. After 15:00, however, small differences emerge. As expected, the traffic volumes on local roads are affected by the BL-based geolocation assignment.

A similar conclusion can be reached from the average speed comparison on three different road types for two assignment methods. With the higher volume, the average speed is lower. Differences in speeds on local roads are observed while computed speeds on freeways remain almost the same.

In addition to the volume comparison in the charts, Figure 10 shows the numerical differences of the two volumes on the map in four time periods. Combined with this map, the BL-based assignment mainly makes impact on the local road rather than the freeways in traffic demand modeling. In summary, first, the location assignment method allocates activities to different locations only within the destination zone. The connection paths between origin and destination zones, which are mostly on freeways, still remain the same. Second, from the chart in Figure 9, the volume computed with BL-based geolocated activities is higher than the one with randomly distributed activities from 17:00 to 23:00. This may be caused by the locations for BL activity assignment is restricted by time, and most business locations are closed in the evening according to business schedules. The activities are assigned to the limited locations which can cause the difference due to spatial aggregation of trips and the average distance per trip is longer at night than the trips during the day time. Therefore, local roads and trips in the evening are influenced more by the BL assignment method.
FIGURE 8: Time of day volume comparison
FIGURE 9: Time of day average speed comparison
(a) Volume difference at 3:00

(b) Volume difference at 9:00

(c) Volume difference at 15:00

(d) Volume difference at 21:00

FIGURE 10 Volume differences between BL-based and random assignment. The volume differences are shown for the period between 3:00 and 21:00.
SUMMARY AND CONCLUSION

In this paper, a new approach is proposed for assigning daily travel activities onto a network using real world business locations and time dependent activity assignment. Before the assignment, real business locations are merged with time of day availability of the employees in these businesses data that are connected to the corresponding activity location in TRANSIMS. With the location pairs, the activities from SimAGENT (the activity based approach of SCAG) are successfully assigned in a directional way. After that, activities serve as input for activity-based travel demand modeling in TRANSIMS. Based on the link-by-link result of traffic volumes and average speed, comparisons are carried out between BL-based geolocation assignment and random assignment. The results from BL-method indicate significant differences in traffic volume estimation on local roads when compared with random assignment procedure. This variation in traffic demand estimation between the two methods needs to be further validated with existing traffic counts on a link-by-link basis to reach definitive conclusions about the performance of the BL-based geolocation assignment procedure. In parallel, a home geolocation assignment is currently developed to complete the method presented in this paper. Moreover, the possibility of business establishments serving different types of activities during a day is also currently examined and may lead us to modify the method presented in this paper (17). Thus, a time-based point-to-point geolocation method for activity assignment can be addressed. Such assignment could bring about many benefits. First, geolocating activities to real business location provides more detailed individual travel route with personal travel purpose considered, thus aiding in developing a finer resolution travel demand model. Second, the detailed route could, in turn, contribute to better analysis of emissions, GHGs and its influence on the environment. Third, the traffic demand modeling and impacts analysis of small areas are both strengthened and enhanced. Fourth, the different times business location is used as destination in different time period could give out another way for the regional traffic impact analysis. From another perspective, since it is local roads that are most impacted by the spatial assignment, in future studies we will need to examine more carefully local roads and develop methods that assign activities along local roads.

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