Comparison of Trip Generation Results from Activity-based and Traditional Four-Step Travel Demand Modeling: A Case Study of Tampa, Florida

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Abstract

There are two main modeling approaches in travel demand forecasting today: one is the traditional four-step travel demand model (FSM) that is being used by the majority of transportation planning agencies, and the other is activity-based model, which simulates individual and household activities at much more detailed levels. The activity-based approach has been viewed as a more advanced method than the traditional four-step model. This paper reports the partial results – trip generations only from a larger research project investigating the differences between the two modeling approaches. In order to do so, a micro-simulation model is developed and used to simulate 24-hour individual daily travel behaviors of the entire population in the Citrus County from Florida, based on survey data that are obtained from Tampa Bay Regional Transportation travel diary records. Corresponding to each step in the traditional four-step travel demand model, trip generation rates, trip distribution, mode choice percentages, and trip assignment results are either directly calculated from the observed or simulated individual daily travel records and are compared with the corresponding results from the Tampa four-step travel demand model (developed elsewhere). Study results show salient differences in modeling performance and accuracy in each of four steps above between four-step and activity-based travel demand approaches. In particular, it is found based on the collected travel diary data from Tampa Bay Region that traditional four-step model tends to overestimate trip production for the low-density area, but tend to underestimate trip production for the high-density area, when compared to the activity-based model. Moreover, analyses to simulated results show that production rates are higher in the four-step model for home-based shopping, home-based social and home-based work trips, but lower for home-based school and home-based other trips. On the other hand, the four-step model shows higher attraction rates for home-based work and home-based sociality trips, but lower rates for all other trips when compared to the activity-based model. It is believed that such differences most likely result from the fundamental modeling philosophy of the two modeling approaches.

1. Introduction

The main assumption behind the activity-based modeling approach treats transportation as the "derived demand" that stems from individual's participations to various socioeconomic activities to achieve their goals. Theory behind the activity-based travel demand models is based on Hagerstrand and his time-geography concept (Hagerstrand, 1970). Activity-based travel demand modeling has been viewed as a more advanced approach compared to the traditional sequential four-step modeling procedure since the activity-based model contains detailed travel information of individuals (e.g. time/duration of trips/activities, location, frequency, sequence, etc), rather than aggregate trip flows from traditional four-step model.

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Walker (2005) provides a direct comparison about the traditional four-step model and the activity-based micro-simulation model for Las Vegas. By discussing key aspects to bridging the gap between theoretical advantages and its implementation of activity-based travel demand, an application of household micro-simulation for Southern Nevada is presented and compared with a more traditional, aggregated model. The result shows how the computation time and calibration efforts are quite similar of the two approaches, but the micro-simulation model offers the additional benefits of preserving demographic distinctions across the population. As a result, it allows for analysis of sub-group impacts that facilitates transportation policy making and investments.

A comparison work of trip generation has been done in Copenhagen by Petersen et al. (2006) between the conventional travel demand model and an activity-based travel demand model developed based on the same data sources. The primary comparison work did not conclude the significant advantages of activity-based model. But the complexity of the activity-based tour generation is mentioned. As nearly all possibilities must be set out up front, a micro-simulation model is needed to remove the unlikely probabilities and avoiding splitting conditions too many times.

Literature review indicates that research for comparing the two modeling approaches is rare and a research project is undertaken to investigate the differences and accuracy of the two according to the four steps (trip generation, trip distribution, mode split and network assignment) used in traditional travel demand modeling. The research compares the modeling results that are obtained from an existing four-step model - The Tampa Bay Regional Planning Model (TBRPM) and the activity-based travel demand models developed by the authors based on the travel diary data collected in the study area of Tampa, Florida. . This paper basically introduces our activity-based modeling approach and reports the comparison results of the first step - trip generation.

2. Study Data and Methodology

In this study, the travel diary data used were collected in Tampa Bay Region Area, Florida, 2007. The study area - Tampa Bay Region has five counties with a total area of 8,482 square kilometer, and a total population of 2,783,236.

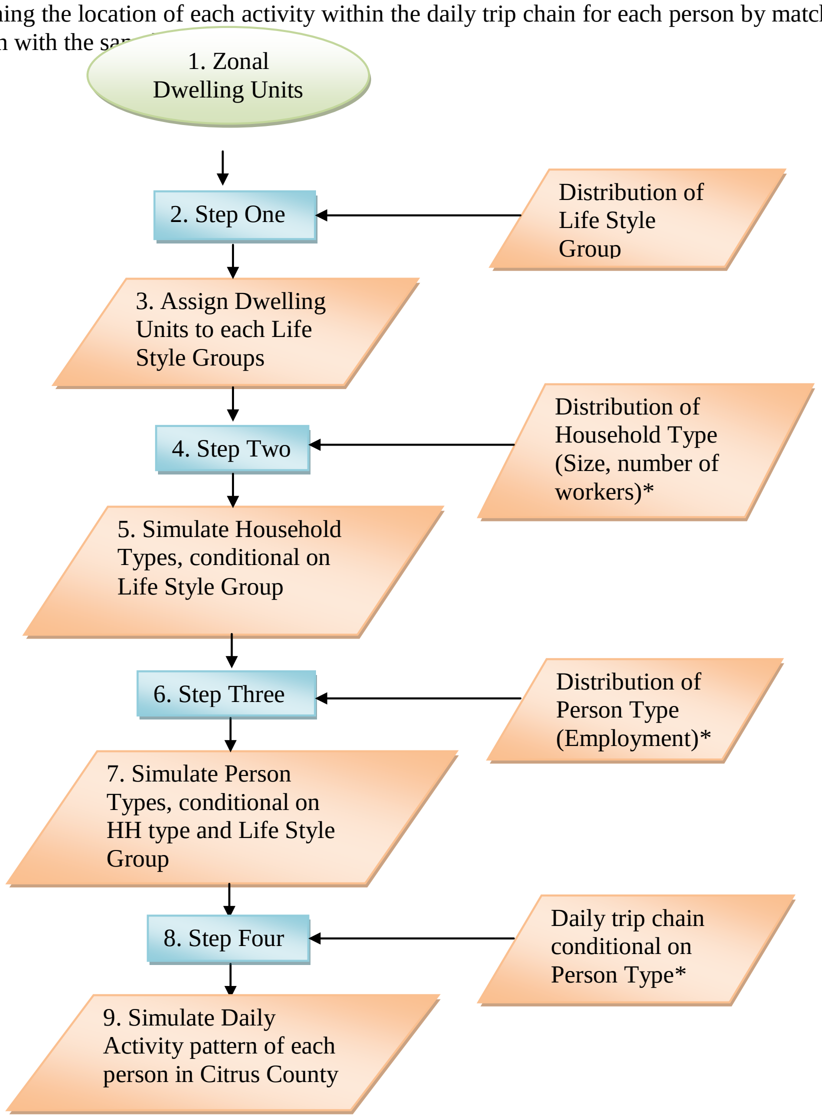
The existing four-step model - Tampa Bay Regional Planning Model (TBRPM) was developed for the planning activities under the Regional Transportation Analysis (RTA) for the Tampa Bay Area. The TBRPM encompasses 2.84 million residents and 1.56 million jobs in the year 2006. And approximately 5,584 system kilometers and 15,202 lane kilometers of highways are simulated within the study area via the planning software CUBE (Technical Report 1- Tampa Bay Regional Planning Model (TBRPM) Version 7.0 , 2010).

Due to the limitation of the sample data, a smaller area- Citrus County is selected as the place of interest to carry out the detailed simulation. Daily travel behaviors of the entire population within the county are simulated. The Tampa Bay Region household travel diary data is used as the basis of the simulation.

A strong assumption of this simulation is that the study area- Citrus County is isolated, in other words, there are no external trips coming in or going out of the county.

Flow charts for presenting the simulation procedure for individual daily activities are shown below. There are two sub-processes: (1). Simulate daily activity pattern for each person in the study area, including activity type, start time and end time, trip length (Figure 1) (2). Select the location of activities, e.g. the destinations of trips, based on the attributes of potential destination zones and the trip distance (Figure 3).

Figure 1 shows the Process One, which designates a daily activity pattern for each resident within the study area. This process includes two parts: the first one is simulating each person in the study area of Citrus County, based on known local demographic data; the second part is assigning the location of each activity within the daily trip chain for each person by matching the person with the sa



* obtained from the survey sample

Figure 1 Flow Chart - Part One

The following outline each procedure in the first process of the simulation.

1. Count the number of dwelling units or households in each Traffic Analysis Zone (TAZ) from Citrus demographic data

2. Classify zonal dwelling units or households into life style groups based on known distribution of lifestyle groups from the data of Tampa Bay Regional Planning Model (TBRPM).

3. Count the number of dwelling units or households in each life style group in a TAZ

4. Conditional on lifestyle group, assign dwelling units or households further into different household types, based on the following two parameters: household size and number of workers in the household. These household types are obtained from the household travel diary data that were collected over the whole Tampa Bay Region area,

5. Count the number of each type of households that is conditioned on life style groups in a TAZ

6. Conditioned on both the household type and the lifestyle group, expanding these dwelling units to the individual level, 'designating' a person type for each household member, which is the employment status, including full-time employment, part-time employment, self-employed, student, retired, and homemaker. These person types are obtained from sample data, which is conditioned on the household type in the sample.

7. Simulate the person type of each household member that is conditioned on both household type and life style group in a TAZ

8. Assign a trip chain to each household member using Monte Carlo method (Figure 2). The trip chains are obtained from the sample data of the whole Tampa Bay Region Area, conditioned on employment type. A random number is used to assign a particular daily trip chain to a given individual.

9. Assign a daily trip chain to each resident of the Citrus County.

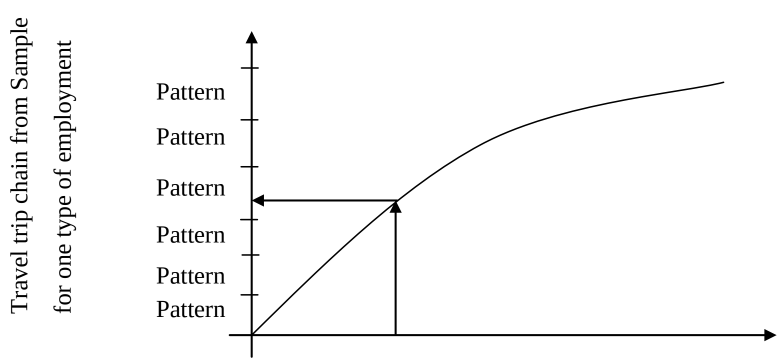


Figure 2 Monte Carlo Trip Chain Assignment

Figure 3 shows the Process Two, which assigns a destination location to each trip within the daily trip chain of each resident simulated in the "Process One" for the entire study area.

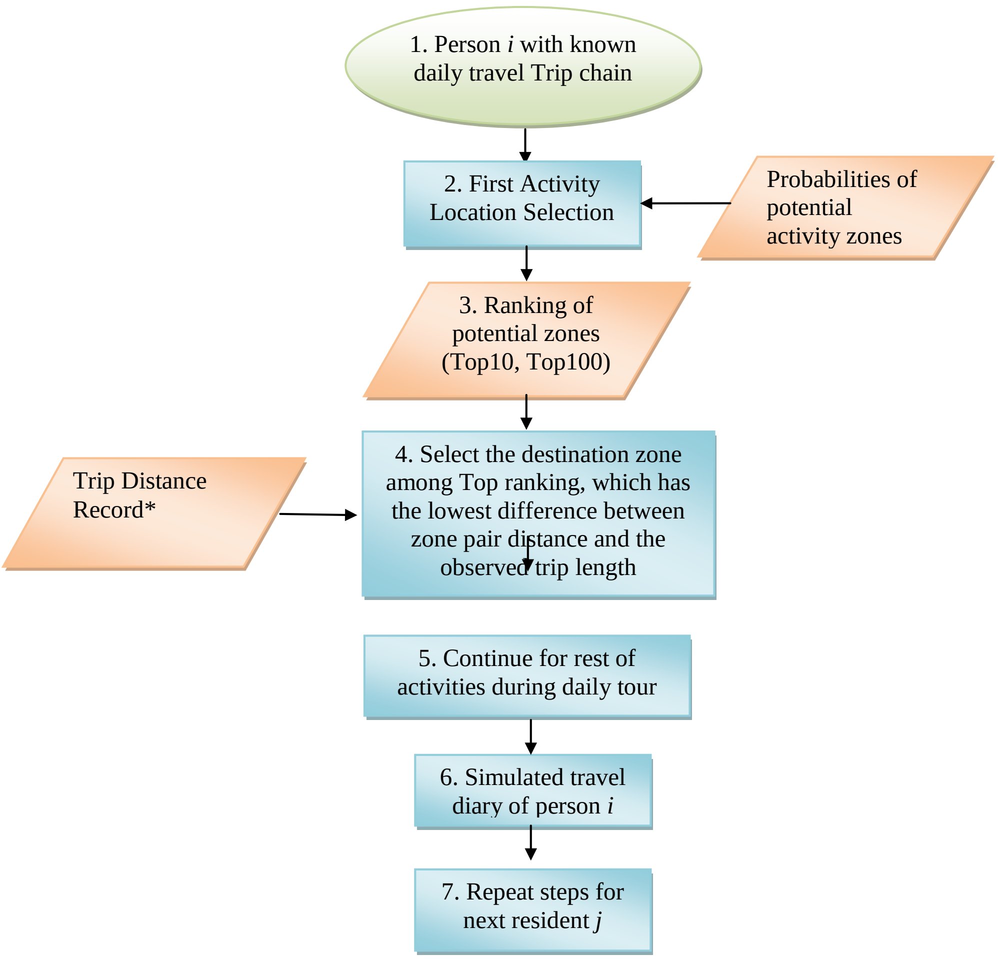


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Figure 3 Flow Chart - Part Two

Detailed procedures of "Process Two" are introduced as following:

1. Process person i with known daily trip chain: after Process One, every resident within Citrus County has an assigned daily trip chain.

2. Calculate the probability of potential destination zones based on the activity type and the characteristics of the zones.

3. Rank the probabilities of potential destination zones. Two scenarios are tested here: Top 10 and Top 100. The difference between these two scenarios is the number of potential destination zones. The choice set for the first scenario includes the top 10 zones with the highest probabilities, while the choice set for the second scenario consists of the top 100 potential zones.

4. Select the activity destination from the choice set of potential zones, with reference to the actual trip distance from the simulated travel diary record. Select the destination zone from the potential choice sets as defined in Step 3, which has the closest trip distance as the observed one from the assigned travel diary record.

5. Continue to simulate the destination of next activity from the daily trip chain of person i.

6. Complete simulating the entire daily trip chain of person *i*.

7. Move on to the next resident *j* after finishing location assignment of the whole trip chain of person *i*.

The activity type, characteristics of the zones and the distance between the origin and the destination are the three factors that are considered to calculate the probability of a zone *j* being selected as the destination zone of one activity.

First of all, a parameter 'zone factor' is defined as a character of the destination zone j. The value of the zone factor depends on the employment density of the destination zone *j*, and also the distance that from the origination zone *i* to the destination zone *j*.

— (1)

Zone factor from origin zone i to destination zone j

Employment density, ——————

The distance between origin zone *i* and the destination zone *j* based on the shortest path.

Please note that in the Equation 1 is defined differently based on the purpose of the trips considered, in other words, varies according to the activity type that will take place in the destination zone. In this thesis, activities are grouped into five classes: home, work, sociality, school, and others. And the following three types of employment: service, commercial and total employments are considered to allocate the five types of activities, using the Equation1above.

For different types of activities (e.g. work vs. school), the value of 'zone factor' of corresponding activity destination zone is calculated based on different employment density (Table 1).

Table 1 Activity Type and Corresponding Employment Density

Activity Type	Corresponding employment density
Work	Total Employment Density
Shopping, others	Commercial Employment Density
Sociality	Service Employment Density

Secondly, after the calculation of the zonal factors for potential destination zones, the probability of choosing the zone j as the activity destination from all potential zones in the study area is calculated as:

(2)

As introduced in Step 3 of the Flow Chart Two, this paper compares the following two scenarios: one is to select the destination zone from a potential choice set consisting of the Top 10 destination zones. The other scenario is selecting the destination zone from a choice set that includes Top 100 high probability zones.

After ranking all potential destination zones based on their probabilities for a trip originating from a zone, the destination zone that has a distance closest to the observed trip distance, which was assigned to the persons being simulated during the simulation sub-process one, will be selected as the destination zone.

Once the destination zone has been chosen, simulation process will move to the next activity until the entire daily tour is completed. Then the simulation process moves to the next resident.

As introduced above, daily travel patterns of the entire population of Citrus County are simulated. Matlab was used to carry out the simulation of the thesis.

After the simulation, the travel diaries of the entire population of the citrus county are known. An origin-destination (OD) matrix can be obtained based on the known travel diary data of the whole population, by simply calculate how many trips are leaving and entering each TAZ. TransCAD is used in this research to assign the OD matrix to the road network.

3. Comparison of Modeling Results

Trip generation is the first step of the four-step travel demand forecasting model. The purpose of trip generation is to estimate the number of the person or vehicle trips that are originating and terminating in each TAZ. This section compares trip generation results through the following two steps. Firstly, trip production rate is calculated directly from Tampa household travel diary data and in the second step, both trip production and attraction rates are calculated from the simulated results for the Citrus County and compared with those from TBRPM.

Cross-Classification method is used in the Tampa Bay Regional Planning Model (TBRPM) to classify the population in the study area into relatively homogenous groups based on certain socio-economic characteristics. The key socioeconomic variables in classifying population group in trip generation in the Tampa Bay Regional Planning Model (TBRPM) are permanent or group quarter's population, dwelling units by lifestyles, and hotel and motel resident type (Technical Report 1- Tampa Bay Regional Planning Model (TBRPM) Version 7.0 , 2010). And then the average trip production rates per household are empirically estimated for each.

On the other side, the trip generation rate of the activity-based approach is directly calculated from Tampa Bay Region household travel diary data. Trips are separated from one person's daily activity participation record, which are referenced by activity type like 'home', 'shopping', 'work', 'school', etc.

As the definition of a 'trip', one trip has two ends: one origin and one destination. To define a trip from the Tampa Bay Region household travel diary data, the type of activity that takes place in the destination is used to determine the 'purpose' of the trip. For example, as shown in Figure 5.6, person A has three activities within one day, starting from 'home' to 'school', followed by an activity of 'other', and then 'home' again. As mentioned above, this person will have three trips: one is from 'home' to 'school', the second one is from 'school' to 'other', and the last one is from 'other' to 'home', in other words, the trips that the traveler A made during the household travel diary data day are 'home-based school' , 'non-home-based other', and 'home-based other'.

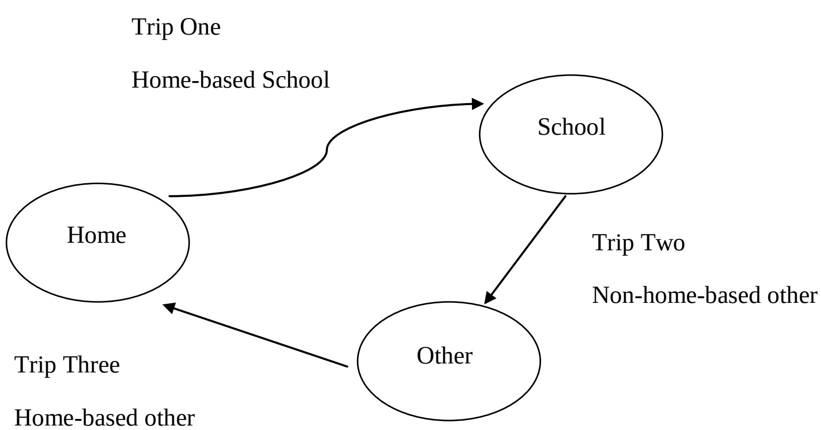

Figure 4 Illustration of Activities and Trips

In order to calculate the trip production rates for the five counties within the study area from household travel diary data, 'production trips', which are defined as the trips that are either originated from or ended at home, need to be identified first. As specified in NCHRP Report 365, trip productions are those trips, which have one end at the traveler's home (Martin, 1998).

Trip production is defined as the home end of a Home-based trip or as the origin of an Non-home-based trip. And trip attraction is defined as the non-home end of a Home-based trip or the destination of a Non-home-based trip (see Figure 5) (Ortuza & G.Willumsen, 2011).

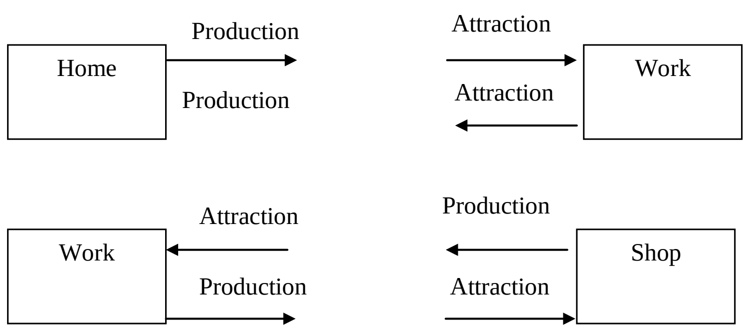

Figure 5 Trip productions and attractions

After that, trip production rates are directly calculated from Tampa Bay Region household travel diary data and are compared with the trip generation rates that are obtained from the Tampa Bay Regional Planning Model (TBRPM). This comparison includes five types of trips: home-based work (HBW), home-based shopping (HBSH), home-based social (HBSR), home-based school (HBSC), and home-based other (HBO). Since the participating households cannot represent all the dwelling units within a particular TAZ in the sample data, and also the non-home-based trips are counted as the production of the actual origin zones, the non-home-based trip types are not included in this comparison.

Table 2 compares the production rates of different types of trips that are obtained from Tampa Bay Regional Planning Model (TBRPM) and the Activity-based Approach (ABA). The differences between the two results are calculated based on the Equation 2 below:

(2)

Table 2 Comparison of Trip Production Rates by Type and County

	Citrus			Hernando		
	FSM	**ABA**	**Difference**	**FSM**	**ABA**	**Difference**
HBW	1.41	0.95	-33%	1.50	1.50	0%
HBSH	0.92	0.66	-28%	0.89	1.19	+33%
HBSR	2.44	1.76	-28%	2.38	0.88	-63%
HBSC	0.76	0.15	-81%	0.92	0.19	-80%
HBO	1.66	1.39	-16%	1.73	1.63	-6%
SUM	7.19	4.90	-32%	7.42	5.38	-28%
	Pasco			**Hillsborough**		
	FSM	**ABA**	**Difference**	**FSM**	**ABA**	**Difference**
HBW	1.63	1.24	-24%	2.01	1.46	-27%
HBSH	0.85	1.18	+38%	0.78	1.01	+30%
HBSR	2.32	2.44	+5%	2.19	1.67	-24%
HBSC	1.02	0.56	-45%	1.32	0.87	-34%
HBO	1.71	1.24	-28%	1.66	1.46	-12%
SUM	7.53	6.65	-12%	7.96	6.48	-19%
	Pinellas					
	FSM	**ABA**	**Difference**			
HBW	1.61	1.67	+4%			
HBSH	0.84	1.11	+33%			
HBSR	2.28	1.78	-22%			
HBSC	0.89	1.11	+25%			
HBO	1.56	1.80	+15%			
SUM	7.18	7.48	+4%			

As can be seen from the above tables, trip production rates are significantly different between the two modeling approaches. The range of the differences is from the lowest -81% for HBSC trips at Citrus County to the highest 38% for the HBSH trips at the Pasco County. The highest overestimation of trip production rates from the FSM occurs in the case of Citrus County with a difference of -32% between the two approaches. For the home-based shopping trips (HBSH), trip production rate from the FSM is five times as that from the ABA. However, in the Pasco County, the FSM underestimates home-based school trips by 38%.

Referring to the demographic data of these five counties (Table 3), it can be found that Pinellas County has the highest population density, followed by Hillsborough. For Pinellas, the activity-based model has higher trip production rates for all of the six trip types except for the home-based social (HBSR), as shown in Table 2. Therefore, it appears that trip production rates are positively correlated with population density.

For lower population density area, like Citrus and Hernando, activity-based approach provides lower trip production rates than the FSM.

Table 3 Demographic Data of Counties 2010

County	Hillsborough	Pinellas	Pasco	Hernando	Citrus
Population	1,229,226	916,542	464,697	172,778	141,236
Area in square mile	1,020.21	273.80	746.89	472.54	581.70
Person per square mile	1,204.9	3,347.5	622.2	365.6	242.8
Total Number of firms	114,841	98,528	38,812	13,476	12,451

Data source: U.S. Census Bureau http://quickfacts.census.gov

It appears that, from the above analysis, the FSM tends to overestimate the trip production for the low-density area (e.g. Citrus County), but tend to underestimate it for the high-density area (e.g. Pinellas County).

In order to compare the production rates of different trip purposes between these two modeling approaches, the histograms of different trip types are also shown below in Figure 6: home-based work (HBW), home-based shopping (HBSH), home-based social (HBSR), home-based school (HBSC), and home-based other (HBO).

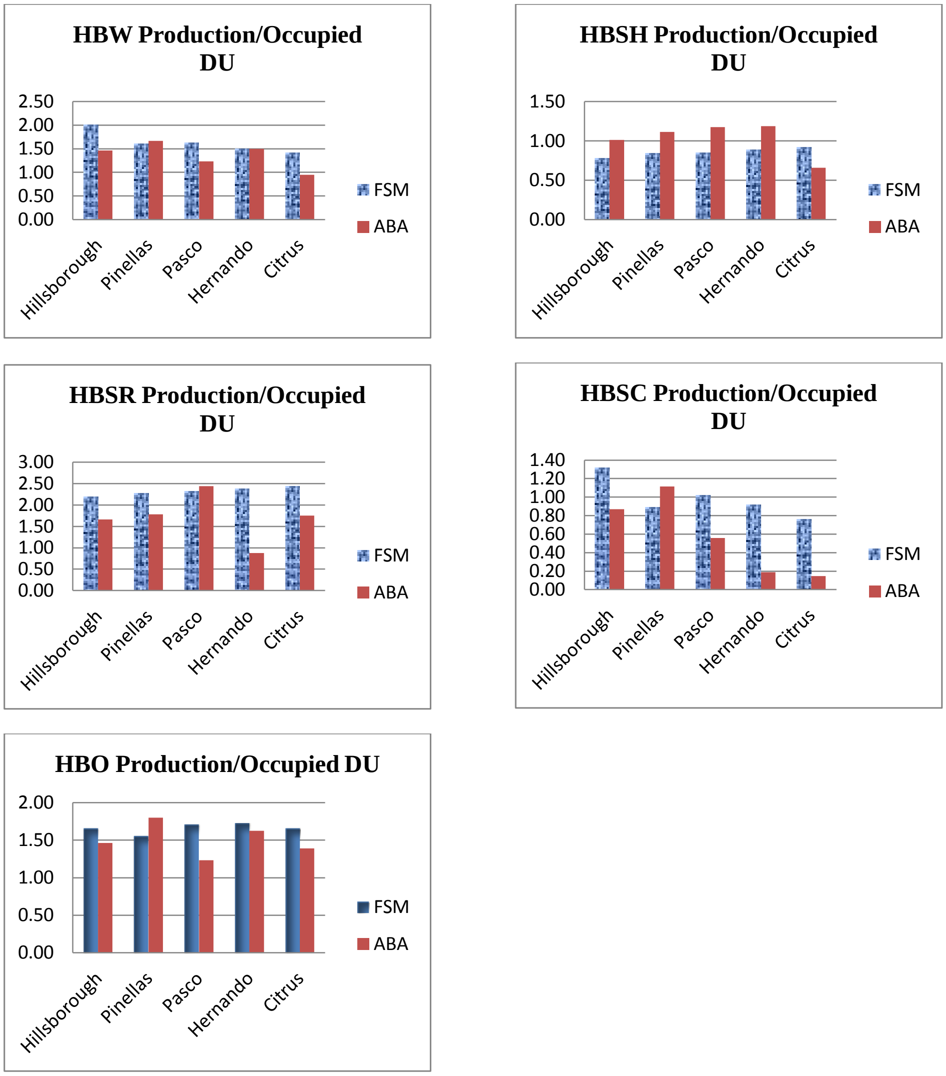

Figure 6 Comparison of Trip Production Rates

For home-based work trip (HBW), the FSM and the ABA have very close trip production rates for Pinellas and Hernando counties. However, the production rate is lower for the ABA than for the FSM in the other three counties.

For home-based shopping trips (HBSH), trip production rate from the ABA is higher than the FSM in all five counties with an average difference of 34%, except for Citrus County. One possible reason is that the four-step models basically ignore ‘intrazonal’ trips that are carried out within one zone, and therefore, these trips are not captured/ reflected in the trip rates.

For home-based social trip (HBSR), the ABA has higher trip production rate than the FSM in Pasco. In the other four counties, social trip production rates are lower for the ABA than the FSM.

The ABA has higher trip production rates than the FSM for home-based school (HBSC) and home-based other trips (HBO) in Pinellas County, while the ABA has lower production rates for these two trip types than the FSM in the other four counties.

In summary, except for Pinellas County, the total trip production rates per dwelling unit from the activity-based model (ABA) are lower than those from the Tampa four-step model (FSM) (Table 4).The comparison of total trip production rates is shown in Figure 7.

Table 4 Difference of Total Trip Production Rates

	Hillsborough	Pinellas	Pasco	Hernando	Citrus
FSM Total	7.96	7.18	7.53	7.42	7.19
ABA Total	6.48	7.48	6.65	5.38	4.90
Difference	-19%	4%	-12%	-28%	-32%

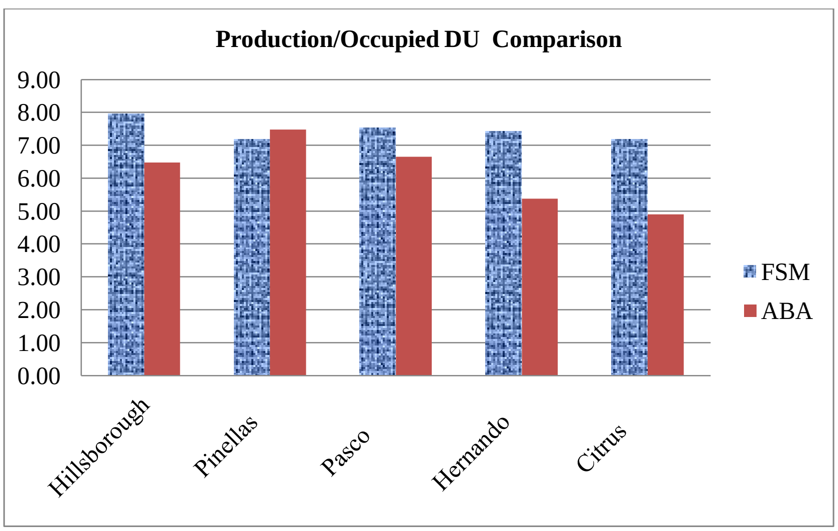

Figure 7 Comparison of Total Trip Production per Occupied Dwelling Unit

In the above, trip production rates are directly calculated from Tampa Bay Region household travel diary data and compared with the results from the four-step model.

However, due to the sampling nature of the survey data, the trip attraction rates cannot be calculated. The following sections carry out the comparison work related to these items based on the simulated daily activities and travel of entire population of Citrus County.

In the simulation results, the daily activity participation and activity locations of every resident of Citrus County are known. Based on that, the number of produced and attracted trips of each TAZ can be calculated by tracking the trips of the entire population.

In this thesis, trip production and attraction are calculated based on the known activities and the sequence of the activity participation. For example, a traveler has been to three places within one day (Figure 8).

The three TAZs are A, B and C. The activity locations are: A is home, B is school and C is other. With the known activity sequence, production and attraction trips of A, B and C can be calculated based on the principles shown in Figure 8 shown before.

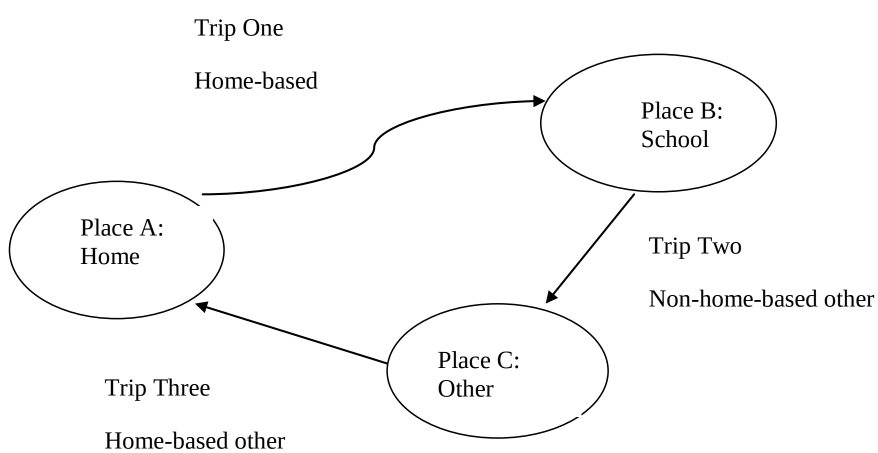

Figure 8 Example of Calculation of Production and Attraction for Each TAZ from Known Daily Travel Pattern

As shown in Figure 8. Place A has two productions; Place B has one production and one attraction; Place C has one production and one attraction too.

Production rate and Attraction rate for each TAZ is calculated based on the functions as below:

$$\overline{\qquad\qquad\qquad} \quad (3)$$

(4)

Two scenarios: Top-10 and Top-100 activity location selection are used in production and attraction rate calculation for different trip purposes, the calculated rates are compared with those from the FSM and shown in Table 5, Table 6, Figure9 and Figure 10.

Table 5 Productions per Total Occupied Dwelling Units

	FSM	TOP-10	PD	TOP-100	PD
HBO	1.66	1.86	12%	1.84	11%
HBSC	0.76	0.99	30%	0.88	16%
HBSH	0.92	0.69	-25%	0.68	-26%
HBSR	2.44	1.98	-19%	1.96	-20%
HBW	1.41	1.22	-13%	1.21	-14%
NHBW	0.26	0.54	108%	0.52	100%
NHBO	0.75	0.89	19%	0.86	15%

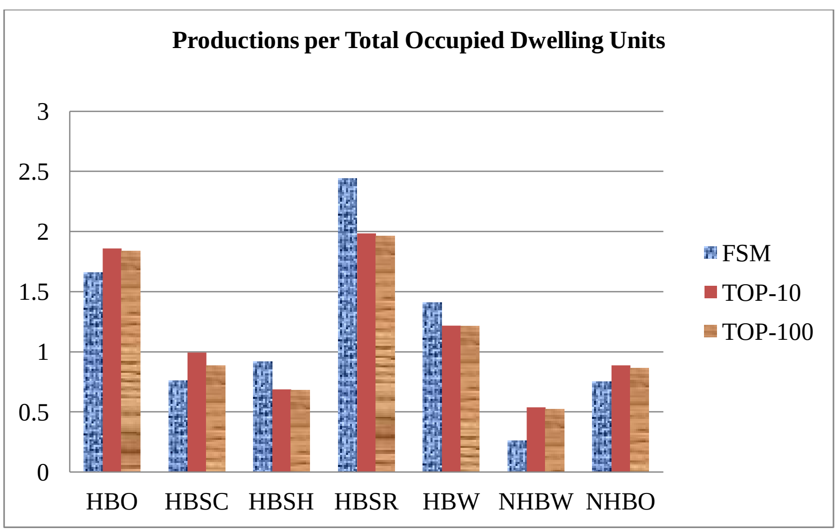

Figure 9 Comparison of Productions per Total Occupied Dwelling Units

As it is shown in Table 5 and Figure 9, production rates are higher in the Four-step model for three trip purposes: Home-based shopping, home-based social and home-based work trips. But they are lower for home-based school and home-based other trips. For non-home based trips, the activity-based approach is found to all have higher production rates.

Table 6 Total Attractions per Employee

	FSM	TOP-10	PD	TOP-100	PD
HBO	2.22	2.52	14%	2.41	9%
HBSC	1.05	1.33	27%	1.20	14%
HBSH	1.14	1.28	12%	1.23	8%
HBSR	3.07	3.02	-2%	2.93	-5%
HBW	1.95	1.76	-10%	1.73	-11%
NHBW	0.36	0.81	125%	0.79	119%
NHBO	1.03	1.35	31%	1.30	26%

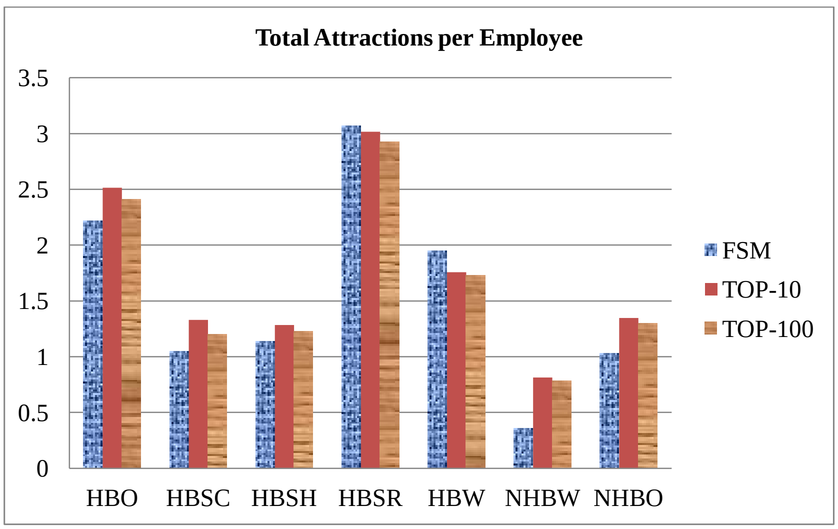

Figure 10 Comparison of Total Attractions per Employee

As shown in Table 6 and Figure 10, the FSM has the higher attraction rates for home-based work and home-based sociality trips than the ABA, but it shows the lower attraction rates for all other trips

4. Conclusion and Summary

This paper presents a comparison between trip generation results from both the activity-based and four-step travel demand model in the study area of Tampa Bay Region, Florida.

Comparison of trip production rates between travel diary data and the TBRPM for the entire Tampa Bay Region indicates a significant difference from the lowest -81% for home-based school (HBSC) trips at Citrus County to the highest 38% for the home-based shopping (HBSH) trips at the Pasco County, using those from TBRPM as the basis. The comparison results of trip production also vary according to counties. The results show that trip production rates are positively correlated with population density. For the county with the highest population density, the travel diary data captures higher trip production rates than the FSM. For lower population density area, like Citrus and Hernando, activity-based approach provides lower trip production rates than the FSM. In other words, the FSM (in this case, TBRPM) tends to overestimate the trip production for the low-density area (e.g. Citrus County), but underestimate it for the high-density area (e.g. Pinellas County).

Comparison of trip production and attraction rates between simulated travel diary data of Citrus County and the TBRPM shows varying results for different trip purposes. Production rates are higher in the FSM for the following three trip purposes: home-based shopping (HBSH), home-based social (HBSR) and home-based work (HBW) trips. But they are lower for home-based school (HBSC) and home-based other (HBO) trips. For non-home based trips, the ABA is found to have higher production rates than the FSM. For trip attraction rates, the FSM has higher rates only for HBSR and HBW trips. The significant differences appear in both trip production and attraction for NHBW, on average, it is 113% more than those from the FSM. The comparison results indicate the incapability of the FSM in capturing the non-home based trips.

In general, it appears that the production and attraction rates used in TBRTM are significantly different with our observed and simulated results. Such differences most likely result from the fundamental modeling philosophy of these two types of model. That is, traditional four-step models use the abstract “trip” to study travel behavior, whereas activity-based model treats travel as a part of larger system – activity patterns.

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