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Mixed Land Use and Travel Behavior: A Case Study for Incorporating Land Use Patterns into Travel Demand Models

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Mixed Land Use and Travel Behavior: A Case Study for Incorporating Land Use Patterns into Travel Demand Models

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Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Community and Regional Planning

The University of Texas at Austin

May 2014

Acknowledgements

I would not have been possible to write this report without the help and support of the kind people around me.

Foremost, I would like to express my sincere gratitude to my principal supervisor, Dr. Ming Zhang. The report would not have been possible without his instructions, patience, support, and immense knowledge. The good advices and support of my second supervisor, Dr. Robert Paterson have been invaluable, for which I am extremely grateful.

I would like to acknowledge the support of the Center for Transportation Research and the Center for Sustainable Development of the University of Texas at Austin. I also thank Dr. Daniel Yang, Mr. Alex Kone and other staff from the Capital Area Metropolitan Planning Organization (CAMPO) for their suggestions.

Last but not least, I would also like to thank my parents in China for supporting my studying in University of Texas at Austin. And thank my friends both in the US and in China, Qianying Zhang, Peter Schulte, Sunxiao Geng, Weijun Zhang, Na Fu, Qian Wu, Kai Zhang, Peirong Ling, Jiayun Ma, Yajun Chen, Xiaojing Ma, Yongcun Feng, Xiaorong Li, Ningneng Xu, Liang Zhang, Yuxuan Chen, Yijie Wang, Haitao Yu, Zhigang Xu, Tianyao Wang, Yi Liu, Xiaomeng Li, Qianqian Zhang, Liqun Chen, and Yang Lei for their encouragement throughout.

For any errors or inadequacies that may remain in the report, the responsibility is entirely my own.

Abstract

Mixed Land Use and Travel Behavior: A Case Study for Incorporating Land Use Patterns into Travel Demand Models

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Abstract:

Metropolitan planning organizations (MPOs) have become increasingly interested in incorporating land use patterns and design ideas into transportation problems. Many design ideas under the umbrella of the New Urbanism; yet in practice they hardly get fully implemented in the standard transportation planning procedures. This research intends to contribute to the continuing debate on land use pattern-travel connection by adding further empirical evidence from the Austin, TX region. Also, it demonstrates ways to integrate land use patterns in transportation demand analysis. The study identifies 42 mixed use districts (MXD) in the Austin region and analyzes the following aspects of travel behavior in MXDs and non-MXDs: production trip rates, frequency of produced trips, network trip length, internal rate of capture, and person-miles of travel (PMT). The study contributes to transportation planning and policy making in Central Texas by providing local empirical evidence on urban form-travel connection. The study's method and process can be of interest to a broad audience in academia and practice.

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1. Introduction

Transportation professionals have become increasingly interested in integrating urban design ideas and land use patterns into transportation issues when seeking solutions to such enduring transportation problems as roadway congestion, vehicle emissions, and traffic accidents. Examples of the design ideas and land use patterns include transit oriented development (TOD), traditional neighborhood design, compact development, mixed use development, and pedestrian/cyclist friendly environmental design. Many planning organizations have created programs to incorporate urban design ideas and land use patterns. In Texas, for example, in the Dallas area, the North Central Texas Council of Governments (CTCOG) is expanding its program of Transit-Oriented Development (TOD) along with the expansion plan of the Dallas Area Rapid Transit (DART) network. In the greater Houston area, the Houston-Galveston Area Council (H-GAC) has been implementing a "Livable Centers" program that promotes clustering development of jobs, shopping, entertainment, and housing

In Austin Metropolitan Statistical Area (MSA), Capital Metropolitan Planning Organization (CAMPO) is currently incorporating a regional growth concept of "Activity Centers" for its 2035 Long Range Transportation Plan. Mixed land use is one important concern to evaluate these "Activity Centers". The Activity Centers concept aims to preserve regional quality of life in the face of continued high growth rates. Through planning and financing future transportation improvements, the growth concept encourages an alternative pattern of land use across the region. Generally, city and neighborhood centers as well as important transportation nodes offer prime locations of activity centers.

While conceptually Activity Centers presents an attractive growth alternative to the capital region, practically it has been a challenging task to apply this concept in

CAMPO's travel demand modeling process. There remain skepticisms on the role that the built environment could play to influence travel behavior. Also, there are technical and institutional issues.

Starting from 2008, one research team sponsored by CAMPO, interviewed by phone the planners or officials, asking them to identify MXD's based on their professional and personal knowledge of their own communities. The interviewee was first given a definition of MXD: "A mixed-use development or district consists of two or more land uses between which trips can be made using local streets, without having to use major streets. The uses may include residential, retail, office, and/or entertainment. There may be walk trips between the uses."

Then, a series of workshops were hosted by the research stuffs and a lot of experts were invited, including planning faculty members in University of Texas at Austin who have decades of working knowledge on land use and community development in Central Texas. Those experts were presented with maps of land use and street network for the study area and asked to draw on the maps the MXD-like developments. CAMPO staff reviewed the preliminary set of MXDs and offered their own identification of MXD samples. In 2009, 42 MXDs were identified as the final sample. This kind of approach is superior to the GIS-only approach as the latter cannot distinguish among different functions that are simply spatially adjacent but actually no synergetic relationships due to physical or non-physical barriers.

This study aims to compare the production trip rates, frequency of produced trips, network trip length, internal rate of capture, and person-miles of travel (PMT) between mixed land use districts (MXD) and Non-MXD to figure out the impact of mixed land use on individual's travel behaviors.

Four years ago, CAMPO had a same kind of study. But that study treated people's trip purposes as only four types: Home based work, Home based non-work, Non-home based work and Non-home based others. In this study, I use the new classification of CAMPO, which includes 12 trip purposes. It shows us more information about impacts on residents' behaviors than the previous one.

Also, by providing metrics commonly used by MPOs, this study's method intends to contribute to incorporating urban design ideas and land use patterns directly into MPO's conventional transportation planning procedures.

The next section reviews the connection between land use and transportation, the impact of build environment on travel behavior, and the integration between land patterns and transportation planning. Then chapter 3 presents site, data, variables and methodology applied in this paper. The section 4 shows the results of the production trip rates, frequency of produced trips, network trip length, internal rate of capture, and person-miles of travel (PMT) between mixed land use districts (MXD) and Non-MXD. After that, a conclusion follows.

2. Literature Review

2.1 LAND USE-TRANSPORTATION CONNECTION

Most of today's vexing problems in the United States like sprawl, air pollution, high living cost and social segregation, have been labeled as results caused by low-density, auto-dependent development pervasive throughout the whole country (Vermont Forum, 2003; Sierra Club 2003). Those problems cannot be treated as either simple land use problems or transportation problems.

Theoretically, land use-transportation connection exists everywhere. As Susan Handy stated (2005), there are two ways in which transportation and land use can be inextricably linked: 1) Transportation investments and policies influence the land development pattern. For example, shop malls, gas stations, and new subdivisions stretch out along the highway corridors after new freeways open. It can be either cause or possible solution to those problems as above. 2) Land development patterns shape individual's travel behavior. One typical example is that the design of single family communities located at suburban areas makes driving a necessity while makes transit and walking almost impossible.

As for the empirical studies, the evidence is a little mixed. Genevieve Guiliano (1995) doubted about the belief that travel choices are strongly influenced by the land use, and that land use changes can be an efficient remedy to controlling automobile use. Her major point is that the relatively low cost and the relatively pervasive accessibility provided by the transportation system today weakened the relationship between transportation and land use. Besides, some scholars (Ryuichi Kitamura, 1997) questioned the notion of causality. One argument is that "certain types of land use patterns attract residents with certain demographic and socio-economic attributes, attitudes and values, and that these attributes of residents are the true determinants of their travel behavior".

Even if land-transportation connection exists, those attitudinal factors or the socio-economic and demographic characteristics of residents may be more strongly related to individual's behavior rather than the land use-transportation system.

On the contrary, Robert Cervero and John Landis (1995) argued that the transportation–land use connection still greatly matters even if transportation costs have declined and accessibility has increased, so that "the connection is undoubtedly much weaker today than it was a century ago." In 2005, Handy compared most of literatures about land use-transportation connection and concluded that, although there are no consensus on to what extent land use is connected to transportation, scholars make four specific propositions about the relationships between them: 1) new highway capacity will influence where growth occurs; 2) new highway capacity might increase travel a little; 3) LRT can encourage higher densities under certain conditions; and 4) new urbanism strategies make it easier for those who want to drive less to do so.

2.2 The Impact of Land Patterns and Design Features on Travel Behaviors

When we talked about the impact of land patterns on travel behaviors, researches can be divided into two groups in terms of how they analyze land pattern: 1) prototypical land patterns; 2) individual land use features. The former categorizes built environment as one single bundling of variables, while the latter argues that different individual land use features differ in magnitude and it's necessary to figure out which features are essential to influence travel behaviors and which are incidental.

For the prototype studies, the land pattern is categorized as either planned unit developments (PUDs) or traditional and neo-traditional neighborhood design (TNDs) (Kulkarni, A., and M. G. McNally, 1997), automobile or transit oriented (Friedman et al, 1994), and urban or suburban (Ewing, 1994). This method is applied in so many studies

because the impacts of those individual features are hard to isolate and methodological problems such as multi-collinearity can be avoided.

In 1995, Kulkami et al gave us a definition on PUD and TND: 1) PUD is the neighborhood with the following features—circuitous and meandering streets, hierarchical street pattern, limited access to the neighborhood, wide streets without street parking, segregated and clustered land uses, low residential densities, large home lots, missing sidewalks and homogenous housing; 2) TND is the one with the following features—interconnected and grid-like street patterns, separated paths for pedestrian and bicycles, on street parking, green space and tree lining, mixed land uses, close proximity of land uses, high residential densities, small home lots, access to activity centers, shaded sidewalks, and different housing design and sizes. According to their research, trip frequency is lower than average in traditional neighborhoods, and higher than average in planned unit developments. Specifically, frequency of transit, walk and bicycle trips is higher in TNDs than in PUDs.

One study of San Diego Association of Governments (1995) showed that in comparison with the rest of regions in San Diego, trip frequency is lower in 13 traditional communities, while walk and bike shares are higher. Rutherford et al (1996) found that in Seattle, trips are shorter in traditional mixed use neighborhoods. Plus, miles travel per person are lower in those mixed used neighborhoods. In addition, Handy's researches (1995, 1996) focused on pedestrian choice. One study in Austin showed that frequency of walk trips to stores is higher in traditional neighborhoods than early modern, and higher in early modern than late modern.

Similar results can also be found in several studies. (Ewing, 1994; Cervero and Radisch, 1995; and Criterion Planners Engineers, 2000) The common conclusion is that 1) trips are shorter in TNDs; 2) the share of walk and bicycle trips is higher in TNDs; and

3) frequency of walk and bicycle trips is higher in TNDs. But the results are mixed for whether trip frequency is lower or higher in TNDs.

Some other studies classify the land prototype according to the resident's major mode choice: auto-oriented, transit-oriented or pedestrian-oriented. Friedman et al (1994) defined auto-oriented neighborhood as one kind of development generally started since the early 1950s with the following features: segregated land uses, well-defined hierarchy of roads, access concentrated at a few points and little transit service. On the contrary, he thinks transit-oriented neighborhood is a mixed use neighborhood close to commercial uses and transit service, and generally was developed prior to WWII. Cervero and Gorham (1995) think besides the features as above, transit-oriented neighborhood is initially built along a transit lane with primarily gridded street pattern.

About the impact of those land patterns on travel behavior, Sasaki Associates' study (1993) looked at the transit and pedestrian-oriented neighborhoods in Montgomery County. The result showed that the transit share is higher in transit and pedestrian-oriented neighborhood. Besides the share of transit, Cervero and Gorham (1995)'s study found that the share of walk and bicycle trips, and the frequency of trips are higher in transit-oriented neighborhoods.

Although the features of land development are codependent in most cases, opponents of those prototype studies argued that the bundling of variables ignores a lot of important information about different individual effects of different features. Different land pattern variables were tested in various studies. Those features include residential densities, employment densities, land use mix index, accessibility, and connectivity.

Some of studies focused on densities. Spillar and Rutherford (1990) collected data from five western U.S Metropolitan areas and tested the impact of the gross population density on transit ridership per capital. They found the transit trip rate rises with densities.

One study of Frank and Pivo (1994) in Seattle area found that higher employment densities and population densities induced higher transit share of work trips and shopping trips, and higher walk share of work trips and shopping trips. Another study by them (1994) focus on the impacts on trip distance and travel time. It is shown that both work and shopping trip distances are shorter with higher population densities and employment densities, while travel times are longer with higher employment and population densities. The same result can be found on Ross and Dunning's study (1997). For the impact on VMT, most of studies (Parsons Brinckerhoff Quade Douglas, 1993; Holtzclaw, 1994; Dumphy and Fisher, 1996; Schimek, 1996; Ross and Dunning, 1997; Frank and Stone, 2000) showed that VMT is lower at higher densities.

Some of studies tested the impacts of land use mixing. Cervero (1991) used 6 U.S Metropolitan area's data and demonstrated that transit share is greater in mixed use and multi-story buildings. The similar result was found in Cambridge Systematics, Inc (1994) and Kockelman (1997), in which it is shown that transit, walk and bicycle share is greater with substantial land-use mixing. Besides, Kockelman's research pointed out that total VMT is lower at locations with higher degree of land-use mixing. In the study of Pushkar et al (2000), Toronto metropolitan area's data also indicated that the average VKT (vehicle kilometers travels) per households is lower at locations with more mixed uses.

Additionally, several scholars looked at the impact of accessibility. In Handy's study (1993), she defined local accessibility in terms of commercial employment within the same zone and defined the regional accessibility in terms of access to particular regional centers. The result showed that shorter shopping trips and lower PMT (person miles traveled) are associate with higher local or regional accessibility. Ewing (1995) demonstrated that VHT (vehicle hours traveled) is lower at more regionally accessible locations. The result that VMT is lower in areas of high accessibility to jobs or high

accessibility to households can also be found on Cervero and Kockelman (1997), Kockelman (1997), Kasuri, Sun and Wilmot (1998) and Pushkar et al (2000).

Connectivity and network design are another factors drawing scholars' attention. Cervero and Kockelman (1997) found that VMT for non-work trips is lower where the proportion of four-way intersections is higher. One study on San Francisco Bay Area (Kitamura et al, 1997) showed that if sidewalks are presented in a neighborhood, the frequency of walk or bicycle trips will increase. Plus, Frank et al (2000) analyzed 1700 households and found that both VMT and VHT is lower in areas with smaller blocks. In additional, one variable—road kilometers per household is added into Pushkar, Hollingworth and Miller's research (2000). The result showed that VKT is lower in locations with curvilinear roads and higher intersection densities, and higher in locations with "rural road networks" and more road kilometers per household. Besides, there are several studies including parking spaces as variable. One common result is that large parking spaces discourage non-auto travel modes (Cervero, 1994; Morrall and Boiger, 1996; and Cervero and Kockelman, 1997).

2.3 THE INTEGRATION OF LAND PATTERNS WITH TRANSPORTATION PLANNING

Different from the debate in academic world, regional transportation plans prepared by Metropolitan Planning Organizations (MPOs), until recently, rarely acknowledge the effects of the land pattern variables as above. In fact, those variables hardly get fully implemented in the standard transportation planning procedure. First and foremost, there remain skepticisms on the role that the built environment could play to influence travel (Echenique, et al, 2012). Second, there are technical and institutional issues (Eash, R. 2013). As of today the majority of MPOs in the US apply the Four-Step modeling procedures (i.e., trip generation, trip distribution, modal split and traffic assignment) for

demand analysis and forecasting. Take the first step, trip generation modeling, as an example. Typically trip productions and attractions are estimated based on the trip rate tables recommended by national agencies such as NCHRP and ITE or developed by local regions (TRB/NRC, 1998). The tables provide trip rates varying along income, household size, vehicle ownership, and metropolitan populations. Land use variables rarely enter into trip generation equations.

There have been two approaches to integrate land use variables into transportation planning practice. One is called the "post-processing" approach (Cervero, R. 2002). This approach takes the output of the conventional four-step models as input and post-processes travel outcome by making empirical adjustments. For example, empirical studies have reported travel behavior elasticities of urban form attributes such as density, land use mixture, and intersection configuration (Ewing, R. and Cervero, R, 2010). The post-processing approach applies the elasticities to adjust up or down the modeled trip volumes, modal splits and other aspects of trip making. While the approach offers an improved solution technically, it may not work due to policy or political constraints.

The second approach is what we call 'pre-processing' (Paul Waddell, 2007), referring to the effort of developing large scale, integrated land use-transport models (Miller, 1998, 1999), for example, UrbanSim (Waddell, P., 2002), PECAS, and region-specific models. The effort attempts to develop new modeling tools that eventually replace the conventional, highway focused four-step modeling procedures. Nevertheless, despite major progress achieved in the field, the integrated land use-transport models remain operational largely in academia. It may take years or even longer for them to become a common practice among MPOs due to known technical and institutional reasons.

In Texas, the Capital Area Metropolitan Planning Organization (CAMPO) in the Austin area is adapting a regional growth concept of "Activity Centers" featured with high-density, mixed use districts (MXD) for its long-range transportation plan. Four years ago, CAMPO had a study (Zhang, 2009) on incorporating land patterns into its transportation planning. But that study treated people's trip purpose as only four type: Home based work, Home based non-work, Non-home based work and Non-home based others.

This paper uses the new classification of CAMPO, which will include 12 trip purposes. It can show more information of residents' behaviors than the previous one. This research aims to compare the production trip rates, frequency of produced trips, network trip length, internal rate of capture, and person-miles of travel (PMT) between mixed land use districts (MXD) and Non-MXD to figure out the impact of mixed land use on individual's travel behaviors. Also, by providing metrics commonly used by MPOs, this study's method lies between the pre-processing and the post-processing approach as mentioned above. Through the case example of Austin, TX, this paper intends to contribute to incorporating land pattern variables directly into MPO's conventional transportation planning procedures.

3. Methodology

3.1 Identification of Mixed Use Districts (MXDs)

Focusing on MXDs was originally part of a national study sponsored by the United States EPA and the Institute of Transportation Engineers (ITE) to improve traffic impact analysis pertaining to MXDs. The Austin region was one of the six cases for the national study (Ewing, et al 2011; Ewing, et al 2012) Identifying MXD's in the Austin region followed a 'bottom up' approach taken by the national study. Specifically, it was based upon local knowledge of city officials, professional planners, CAMPO staff and academic experts. The process involved three working steps. First, a list of 49 communities in the region was created and the contact information of representative planners or public officials collected. The research team then interviewed by phone the planners or officials, asking them to identify MXD's based on their professional and personal knowledge of their own communities. Instructed by the national study, the interviewee was first given a definition of MXD: "A mixed-use development or district consists of two or more land uses between which trips can be made using local streets, without having to use major streets. The uses may include residential, retail, office, and/or entertainment. There may be walk trips between the uses."

The MXD definition given in this study was relatively expansive and inclusive in order to garner a significant number and variety of samples for statistical analysis. The study did not establish criteria for minimum size, density, or number of land uses for a MXD. A general reference is the area reachable by walking. For example, a circle of ¼~ ½ -mile in radius has an area of approximately 125~502 acres. Downtown districts (excluding downtown Austin) and traditional neighborhoods were the primary areas cited by local planners.

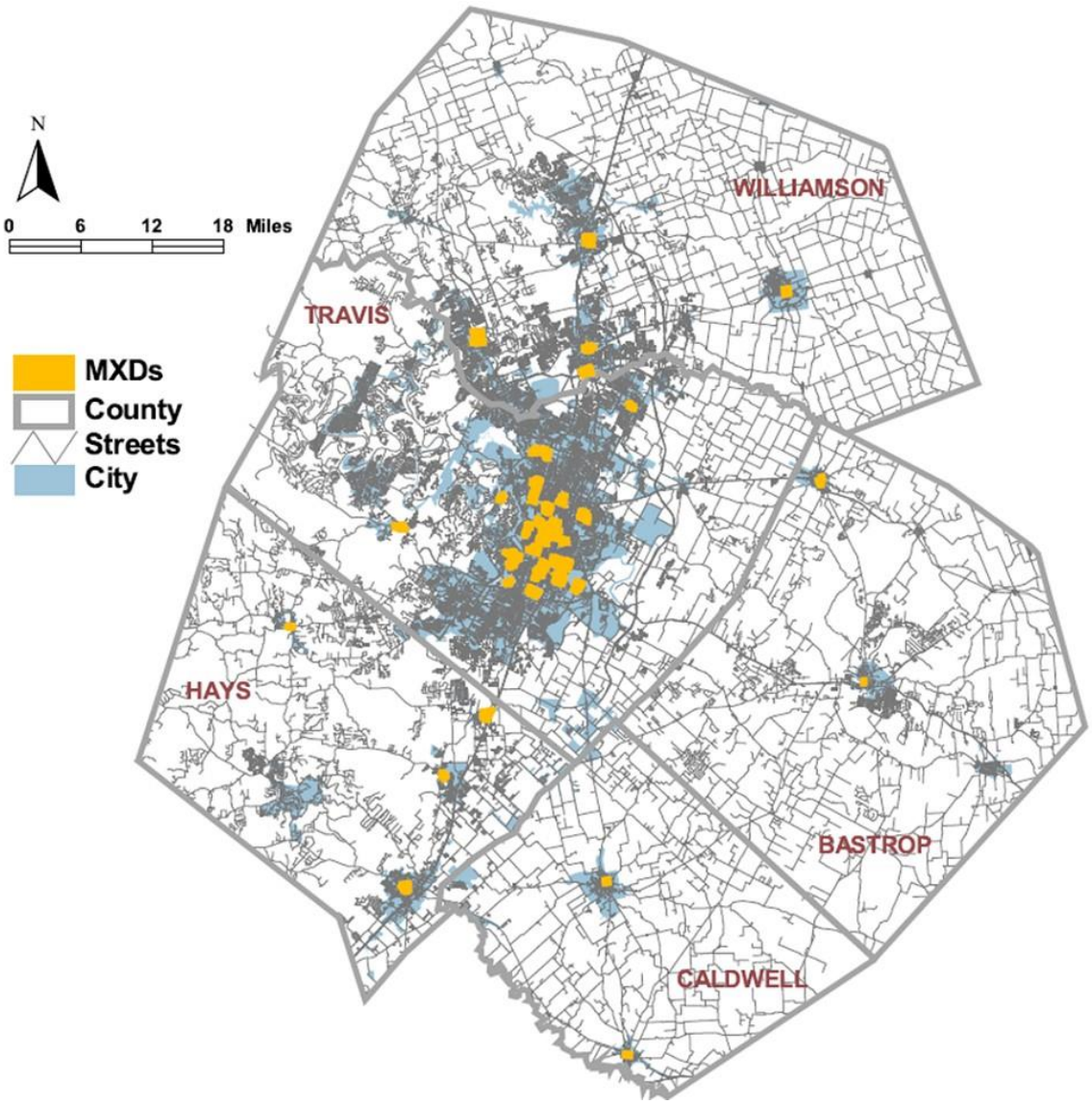

Figure 1: Identification of Mixed Use Districts (MXDs) in Austin MSA

The second step includes two work sessions with experts from CAMPO and from the University of Texas at Austin (UTA). The experts were presented with maps of land use and street network for the study area and asked to draw on the maps the MXD-like developments. CAMPO staff reviewed the preliminary set of MXDs and offered their own identification of MXD samples. UTA planning faculty members who have decades

of working knowledge on land use and community development in Central Texas were invited to provide their expert knowledge of Central Texas geography and urban planning.

Finally, the research team using land use GIS and Google aerial photos refined the MXDs identified from previous steps and finalized the boundaries of the MXD's to complete the sample set. The final sample set contains 42 MXD's in the region. The expert-GIS combined approach is superior to the GIS-only approach as the latter cannot distinguish among different functions that are simply spatially adjacent but actually no synergetic relationships due to physical (e.g., a fence not recorded in the GIS database) or non-physical barriers.

In this study, if one Transportation Area Zone (TAZ) contains part of MXD, this TAZ is identified as "MXD-influenced TAZ". Plus, if someone's home is located in MXD-influenced TAZ, this observation point will be marked as "MXD". Otherwise, the record will be marked as "NON_MXD".

The following table reports descriptive statistics of the households located inside and outside MXDs. Notably, households outside MXDs having an average number of 2.82 persons per household are larger than those inside MXDs (2.29 persons per household). The statistical test of difference in sample means suggests that the difference in average household size is significant. This difference exists mainly due to a larger number of non-working dependents in non-MXD households than MXD households (The MXD and non-MXD households appear to have the same average number of workers). On average, MXD households exhibit similar characteristics to the average non-MXD households in terms of income, vehicle ownership, and tenure.

Table 1: Descriptive Statistics

Variable	HH Inside MXDs (n=65)				HH Outside MXDs (n=1,354)				t-test
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	
# Persons in HH	2.29	1.2	1	5	2.82	1.54	1	13	-2.75
# Workers in HH	1.08	0.83	0	2	1.12	0.8	0	2	-0.44
Income/Person (2005 $1000s)	22.21	17.19	2.5	87.5	22.92	18.47	0.83	150	-0.3
Vehicles in HH	1.8	0.96	0	4	1.91	0.91	0	7	-0.93
Vehicles/Person	0.87	0.46	0	3	0.79	0.41	0	5	1.59
Vehicles/Worker	1.24	0.46	0	2	1.41	0.71	0	5	-1.54
Bikes in HH	0.85	1.39	0	7	1.67	7.2	0	99	-0.92
Years in Residence	3.8	1.73	0	5	3.98	1.58	0	5	-0.89

3.2 CLASSIFICATION OF TRIP PURPOSES

In this study, I will apply the new classification of trip purposes from CAMPO, which will include 12 trip purposes. The definitions for 12 trip purposes are listed as below:

1) HBWD: Home Based Work Person Trips Direct.

   HBWD trip is part of a trip "tour" that consists of both home-to-work and work-to-home trips as being direct. If either trip is not direct, then neither is considered to be direct. The exception to this rule has to do with "trip linking". In this study, if the distances of the intermediate stops and home or the intermediate stops and workplaces are less than 5 minutes (that what I use to define the trip purpose, CAMPO may use other way to define the "convenient point"), then these stops are called "convenient point" and are "linked out", and both the home-to-work and work-to-home trips remain Direct.

2) HBWS: Home Based Work Person Trips Strategic

HBWS trip contains an intermediate destination to either drop off or pick up a child at day-care, nursery school, baby sitter, pre-school, elementary or secondary school. If a traveler drops off their child at a day-care center in the morning yet proceeds directly home in the evening, then both trips are considered Strategic. This is the only case of serve passenger which is "linked out" to create a composite HBW Strategic trip.

3) HBWC: Home Based Work Person Trips Complex

HBWC trip is part of a trip "tour" that consists of one trip between home and work and another trip between home and work which involves an intermediate stop at any destination. In this case, the home-to-work leg of the trip chain would be coded as HBWC, the work-to other leg of the chain would be coded as NHB and the other-to-home leg of the chain would be coded as HBNW.

4) HBNWR: Home Based Non-work Retail Person Trips

5) HBNWO: Home Based Non-work Other Person Trips

6) HBNWE1: Home Based Non-work Primary Education Person Trips

7) HBNWE2: Home Based Non-work University/College Person Trips

8) NWAIR: Non-work Airport Person Trips

9) NHBW: Non-home Based Work-related Person Trips

10) NHBO: Non-home Based Other Person Trips

11) TRTX: Commercial Truck/Taxi Vehicle Trips

If the trips cannot defined as (1) ~ (2), and the trip purpose is not work related or home related, and the travel mode is truck or taxi, I defined that trip as (11).

12) EXTER: If either Origin point or End point is outside of the "5 counties", that trip will be defined as (12).

3.3 GEOCODING OF TRIPS IN GIS

Most of the data is provided by Center for Transportation Research (CTR) in University of Texas at Austin and CAMPO. Because my study will focus on transportation issues, network analysis is necessary and the street data of Austin is needed (from CAMPO). The trips data is from the 2005 Austin Activity Travel Survey. The detailed data sources are listed as below:

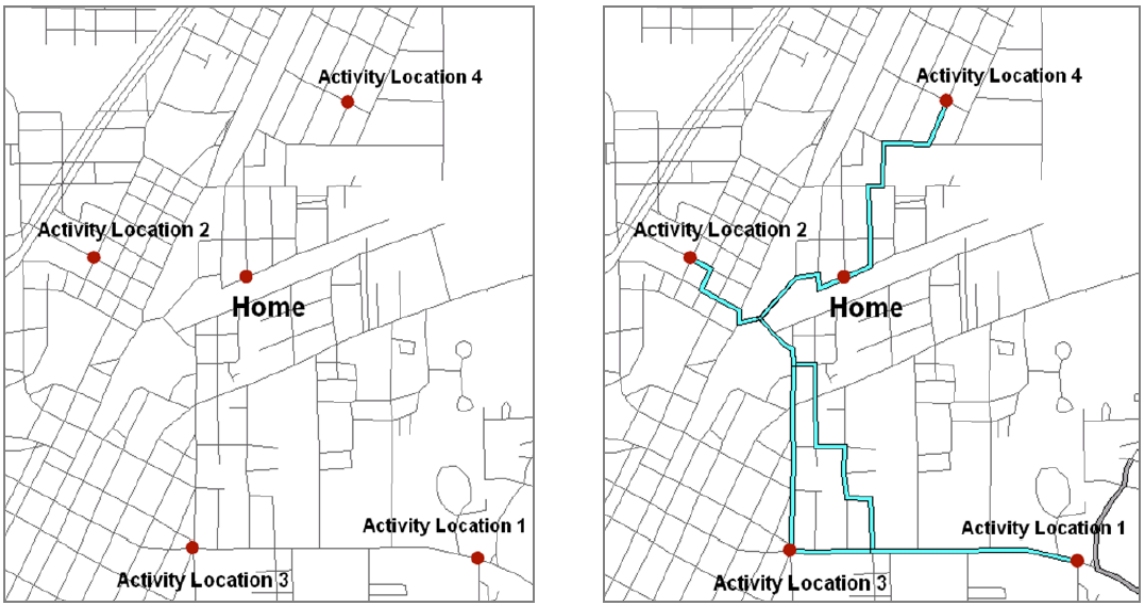

Figure 2: Geocoding of Trips

1) 2005 Austin Activity Travel Survey—CAMPO;
2) TAZs Geo-dataset—CAMPO;
3) Loaded Road network—CAMPO;
4) MXD Boundary—CTR;
5) 2010 Land use data and other demographic data—City of Austin.

The survey records geographic coordinates of activity locations and trip ends (origins and destinations) of the surveyed travelers. These trip ends are geocoded in

TransCAD and ArcGIS. Network distance is estimated based on the assumption that the traveler took the shortest path in network distance between trip origin and destination.

Also, because I will compare MXD and Non-MXD, I will use some vector analyzing tools in TransCAD or ArcGIS. Besides, some overlay and summary analysis are used for calculating PMT. The detailed workflow is as below:

1) Geocode starting points and ending points of trips to two geographic files: "Trips_O" and "Trips_D" using the address information in "2005 Austin Activity Travel Survey". Then refine the geocoding results.
2) Join different activity tables with activity geographic files to get information as much as possible.
3) Use SQL Query to classify different trip purposes and fill "Trip purpose" field. (See Appendix)
4) Intersect TAZs geographic file with "Trips_O" and "Trips_D" and then run summary analysis to know which TAZ those starting points and ending points are located within.
5) Use "Clip" and boundary information to delineate MXD boundaries. Then we use overlay analysis to tag TAZs geographic file with MXD information.
6) Intersect MXDs geographic file with "Trips_O" and "Trips_D" and then run summary analysis to know which MXD area those starting points and ending points are located within.
7) Build the network dataset using Loaded Road network.
8) Use "calculate locations" tool to get geometric info of starting points and ending points in the established network. Then repeat this step with different "snap tolerance" to input geometric info to every point.

9) Create a new route and load information of one starting point and its corresponding ending point to "Stops". Repeat this for rest of points.

10) Solve the route in ArcGIS to get total path length information for every route. (mark it as DIST_OD)

11) Repeat 7) ~ 10) but use home location and Trips_D to get path length between ending points and home locations. (mark it as DIS_HD)

12) Use query tool to identify whether a route is an internal captured trip or not.

13) Summarize DIS_OD using "Person ID" and "MXD ID" to calculate PMT for people living in MXDs and those living in Non-MXDs.

3.4 TABULATION OF TRIP RATES TABLES

In this research, trip rate tables are estimated in two ways: S0 and S1. The definition of the two approaches are as below:

1) S_0

   I assume that there are no difference between MXD area and NON_MXD area. After I get the trip production generation, I split the generation table into two parts as I defined above: MXD and NONMXD. But these two parts use the same trip rate table.

2) S_1

   In the trip survey data, I picked up all MXD data to estimate the trip rate table for MXD. Then I picked up all NONMXD data to estimate the trip rate table for NONMXD. So there are two sets of trip rate tables. When calculating the trip generation, I used trip rate tables for MXD to calculate the trip generation for MXD. Then I used the same way but with trip tables for Non-MXD to calculate

the trip generation for NON_MXD. After that, I combined the two trip generations to get total trip generation result.

For both S_0 and S_1, three-way Cross-Classification was used to estimate the HBW trip rates tables. The variables include as below:

1) Household size: "HHSIZE05" in TAZ geographic file,

2) Medium income group: "MEINCGRP05" in TAZ geographic file,

"1" refers household income less than $20,000;

"2" refers household income between $20,000 and $35,000;

"3" refers household income between $35,000 and $50,000;

"4" refers household income between $50,000 and $75,000;

"5" refers household income more than $75,000

3) Employed population in household (EMP_HH):

I use Survey data and two-way classification way to count how many "workers in one household" in different income and household size level. The estimation is as below. Then for one TAZ, with specific income and household level, I applied the estimated value for that TAZ.

Table 2: Estimation of Employed Population in the Household

Household Size	Medium Income Group	EMP_HH
1	1	0.27
1	2	0.45
1	3	0.63
1	4	0.73
1	5	0.74
2	1	0.59
2	2	0.85
2	3	1.11
2	4	1.14
2	5	1.22
3	1	0.85
3	2	1.35
3	3	1.69
3	4	1.79
3	5	1.75
4	1	1.31
4	2	1.67
4	3	1.86
4	4	1.77
4	5	1.68
5	1	0.97
5	2	1.81
5	3	2.22
5	4	1.89
5	5	1.68

For tabulation of trip tables for other trip purposes, two-way classification is applied and “EMP_HH” is not taken into account for those estimations.

3.5 ESTIMATION OF MISSING DATA

Because there are not enough observation points for some trip purpose if we just consider the survey data in MXD areas, there are no households with specific characteristic in terms of income and household size. But it is obviously wrong to set zero for the trip rates of these specific kinds of households. In this study, three methods were used to deal with the missing data in trip rates tables, marked as “REG”, “MEAN” and “REG_MIS”

1) REG

Based on existing trip rates from Cross-Classification, this method uses multi-variable regression to build the relationship among trip rates and variables used in Cross-Classification (income, household size, and “workers in one family”), and then estimate all trip rates using the estimated equation to get new trip rates tables. It means that this method will not only to fill the missing data, but also replace the previous trip rates from Cross-Classification.

Although, this way can fill most of missing data and data with extremely high value in trip rates tables, the data to build the regression is not enough to get the convincing result. Therefore the estimated rate looks, albeit nice, but cannot reflect the real situation. In one word, this method over-adjust raw data, so people may doubt about the result.

2) MEAN

This method applied Cross-Classification first and then borrows the whole-area-wide average trip rate for specific trip purpose as the estimate for missing data.

In comparison with REG, this way is closer to the real situation because I use the original survey data and Cross-Classification to get the trip rates. However, there many odd values in trip rate tables because of the low volume of observation points. Besides, using average trip rates to fill the missing data ignores the trend.

3) REG_MIS

This method will use the method as REG to get the estimated equation, but just fill the missing value using the estimated trip rates.

This method is closer to the real situation, even better than MEAN, because this method consider the effect of trend. Also, it did not change too many trip rates from Cross-Classification. Although there are still some odd values in trip rates tables, the result is much better than MEAN.

4. Empirical Results Analysis

This study's major interests are the differences in people's travel behaviors between those who associate (living in, traveling from or to) with the MXDs and those who do not. Five aspects of travel behavior analyzed include trip production rates, frequency of produced trips, trip network length, internal rate of capture, and person miles traveled (PMT).

4.1 TRIP PRODUCTION RATES

As mentioned above, this study applied two approaches to estimate the trip rates tables: S_0 and S_1. For each approach, 12 trip tables are listed based on different trip purposes.

4.1.1 Trip Rates under S_0

Different trip rates tables for different trip purposes are listed as below. The first row in the three-way cross-classification tables refers to the different household sizes.

Table 3: Trip Rates for HBWD under S_0

Trip Rates (HBW_D)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.99	1.07	1.16	1.25	1.34
	2	1.06	1.16	1.28	1.37	1.49
	3	1.14	1.25	1.37	1.48	1.58
	4	1.22	1.35	1.47	1.57	1.70
	5	1.31	1.46	1.61	1.73	1.83
Two+ Workers	1	0.00	1.52	1.64	1.78	1.94
	2	0.00	1.81	1.91	2.06	2.21
	3	0.00	2.01	2.13	2.24	2.40
	4	0.00	2.19	2.32	2.43	2.55
	5	0.00	2.29	2.42	2.54	2.64

Table 4: Trip Rates for HBWS under S_0

Trip Rates (HBW_S)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.00	0.00	0.00	0.33	0.11
	2	0.00	0.00	0.13	0.00	0.00
	3	0.00	0.00	0.00	0.11	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.18	0.00
Two+ Workers	1	0.00	0.00	0.33	0.67	0.00
	2	0.00	0.00	0.19	0.33	0.10
	3	0.00	0.00	0.34	0.13	0.07
	4	0.00	0.00	0.27	0.21	0.00
	5	0.00	0.00	0.40	0.35	0.13

Table 5: Trip Rates for HBWC under S_0

Trip Rates (HBW_C)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.00	0.00	0.00	0.33	0.11
	2	0.00	0.00	0.13	0.00	0.00
	3	0.00	0.00	0.00	0.11	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.18	0.00
Two+ Workers	1	0.00	0.00	0.33	0.67	0.00
	2	0.00	0.00	0.19	0.33	0.10
	3	0.00	0.00	0.34	0.13	0.07
	4	0.00	0.00	0.27	0.21	0.00
	5	0.00	0.00	0.40	0.35	0.13

Table 6: Trip Rates for HBNWR under S_0

Trip Rates (HBNW_R)					
Income	One	Two	Three	Four	Five+
1	1.12	2.05	2.60	0.92	1.56
2	0.90	1.53	1.21	1.20	1.16
3	1.04	1.28	1.69	1.33	2.18
4	1.22	1.75	2.02	2.02	2.11
5	1.06	1.66	1.32	2.10	1.52

Table 7: Trip Rates for HBNWO under S_0

Trip Rates (HBNW_O)					
Income	One	Two	Three	Four	Five+
1	1.08	1.97	2.47	3.85	5.31
2	0.92	1.75	2.15	3.46	6.09
3	0.71	1.75	1.76	3.69	5.91
4	0.61	1.46	2.29	3.45	7.42
5	0.76	1.20	2.54	5.01	7.44

Table 8: Trip Rates for HBNWE1 under S_0

Trip Rates (HBNW_E1)					
Income	One	Two	Three	Four	Five+
1	0.00	0.08	0.80	2.23	3.53
2	0.00	0.06	0.89	2.17	4.06
3	0.00	0.05	0.71	2.29	3.00
4	0.00	0.02	0.69	2.31	3.06
5	0.00	0.02	0.80	2.15	3.46

Table 9: Trip Rates for HBNWE2 under S_0

Trip Rates (HBNW_E2)					
Income	One	Two	Three	Four	Five+
1	0.05	0.13	0.27	0.08	0.31
2	0.00	0.01	0.11	0.00	0.06
3	0.05	0.04	0.16	0.02	0.12
4	0.00	0.09	0.02	0.12	0.11
5	0.00	0.02	0.12	0.17	0.13

Table 10: Trip Rates for NWAIR under S_0

Trip Rates (NW_AIR)					
Income	One	Two	Three	Four	Five+
1	0.00	0.04	0.00	0.00	0.00
2	0.00	0.01	0.00	0.10	0.00
3	0.04	0.03	0.02	0.00	0.00
4	0.04	0.04	0.00	0.05	0.06
5	0.12	0.04	0.13	0.12	0.00

Table 11: Trip Rates for NHBW under S_0

Trip Rates (NHB_W)					
Income	One	Two	Three	Four	Five+
1	0.08	0.16	0.33	0.77	0.38
2	0.32	0.59	0.51	0.51	0.63
3	0.38	0.59	0.61	1.21	0.94
4	0.52	0.59	1.16	1.29	1.58
5	1.06	1.05	1.53	1.38	2.19

Table 12: Trip Rates for NHBO under S_0

Trip Rates (NHB_O)					
Income	One	Two	Three	Four	Five+
1	0.96	1.05	2.13	1.85	2.38
2	0.82	1.23	0.91	1.07	2.22
3	0.73	1.05	1.00	1.52	3.42
4	0.83	1.34	1.27	1.95	4.58
5	0.76	1.14	1.75	3.14	4.71

Table 13: Trip Rates for TRTX under S_0

Trip Rates (TRTX)					
Income	One	Two	Three	Four	Five+
1	0.18	0.24	0.33	0.62	0.66
2	0.03	0.17	0.13	0.27	0.00
3	0.18	0.06	0.16	0.08	0.39
4	0.00	0.06	0.09	0.05	0.33
5	0.00	0.12	0.14	0.13	0.15

Table 14: Trip Rates for EXTER under S_0

Trip Rates (EXTER)					
Income	One	Two	Three	Four	Five+
1	0.00	0.03	0.00	0.00	0.00
2	0.08	0.16	0.04	0.15	0.00
3	0.11	0.26	0.04	0.19	0.15
4	0.13	0.11	0.04	0.26	0.11
5	0.12	0.26	0.07	0.02	0.06

4.1.2 Trip Rates under S_1

In this section, MXD and Non-MXD are divided. Also three ways as mentioned before were used for estimation of missing data.

Table 15: Trip Rates for HBWD (Non-MXD) under S_1

Trip Rates (HBW_D) (Non-MXD)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	1.05	1.31	1.38	1.33	1.11
	2	1.57	1.73	1.70	1.50	1.67
	3	1.38	1.29	1.88	1.28	0.80
	4	0.87	1.11	1.57	1.07	1.00
	5	0.92	1.57	1.22	1.00	1.71
Two+ Workers	1	0.00	1.75	2.80	2.00	2.40
	2	0.00	3.05	3.24	2.64	3.21
	3	0.00	2.58	2.44	2.69	3.11
	4	0.00	2.87	3.31	1.68	2.88
	5	0.00	2.69	2.42	1.67	2.96

Table 16: Trip Rates for HBWD (MXD) under S_1 by using REG

Trip Rates (HBW_D) (MXD_REG)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	1.58	1.59	1.60	1.61	1.62
	2	1.50	1.51	1.52	1.53	1.54
	3	1.41	1.42	1.43	1.44	1.45
	4	1.33	1.33	1.34	1.35	1.36
	5	1.24	1.25	1.26	1.27	1.28
Two+ Workers	1	0.00	3.37	3.38	3.39	3.40
	2	0.00	3.29	3.30	3.30	3.31
	3	0.00	3.20	3.21	3.22	3.23
	4	0.00	3.11	3.12	3.13	3.14
	5	0.00	3.03	3.04	3.05	3.06

Table 17: Trip Rates for HBWD (MXD) under S_1 by using MEAN

Trip Rates (HBW_D) (MXD_MEAN)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	1.03	1.03	1.00	1.03	1.03
	2	2.00	2.00	2.00	1.03	1.03
	3	1.00	2.00	1.03	2.00	1.03
	4	0.00	1.03	1.03	1.03	1.03
	5	1.03	1.03	1.03	1.03	1.00
Two+ Workers	1	0.00	1.03	2.00	1.03	1.03
	2	0.00	8.00	1.03	3.00	2.00
	3	0.00	0.00	3.00	1.03	4.00
	4	0.00	1.60	4.00	1.03	1.03
	5	0.00	4.00	2.67	4.00	1.03

Table 18: Trip Rates for HBWD (MXD) under S_1 by using REG_MIS

Trip Rates (HBW_D) (MXD_ REG_MIS)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	1.58	1.59	1.00	1.61	1.62
	2	2.00	2.00	2.00	1.53	1.54
	3	1.00	2.00	1.43	2.00	1.45
	4	0.00	1.33	1.34	1.35	1.36
	5	1.24	1.25	1.26	1.27	1.00
Two+ Workers	1	0.00	3.37	2.00	3.39	3.40
	2	0.00	8.00	3.30	3.00	2.00
	3	0.00	0.00	3.00	3.22	4.00
	4	0.00	1.60	4.00	3.13	3.14
	5	0.00	4.00	2.67	4.00	3.06

Table 19: Trip Rates for HBWS (Non-MXD) under S_1

Trip Rates (HBW_S) (Non-MXD)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.00	0.00	0.00	0.50	0.17
	2	0.00	0.00	0.22	0.00	0.00
	3	0.00	0.00	0.00	0.17	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.26	0.00
Two+ Workers	1	0.00	0.00	0.60	1.00	0.00
	2	0.00	0.00	0.29	0.55	0.16
	3	0.00	0.00	0.56	0.19	0.11
	4	0.00	0.00	0.46	0.32	0.00
	5	0.00	0.00	0.63	0.50	0.26

Table 20: Trip Rates for HBWS (MXD) under S_1 by using REG

Trip Rates (HBW_S) (MXD_REG)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.07	0.10	0.13	0.16	0.20
	2	0.00	0.03	0.06	0.09	0.13
	3	0.00	0.00	0.00	0.03	0.06
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
Two+ Workers	1	0.00	0.24	0.27	0.30	0.33
	2	0.00	0.17	0.20	0.23	0.26
	3	0.00	0.10	0.13	0.16	0.20
	4	0.00	0.03	0.06	0.10	0.13
	5	0.00	0.00	0.00	0.03	0.06

Table 21: Trip Rates for HBWS (MXD) under S_1 by using MEAN

Trip Rates (HBW_S) (MXD_MEAN)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.06	0.06	0.00	0.06	0.06
	2	0.00	0.00	0.00	0.06	0.06
	3	0.00	0.00	0.06	0.00	0.06
	4	0.00	0.06	0.06	0.06	0.06
	5	0.06	0.06	0.06	0.06	0.06
Two+ Workers	1	0.00	0.06	0.00	0.06	0.06
	2	0.00	0.00	0.06	1.50	0.00
	3	0.00	0.00	0.00	0.06	0.00
	4	0.00	0.00	0.00	0.06	0.06
	5	0.00	0.00	0.00	0.00	0.00

Table 22: Trip Rates for HBWS (MXD) under S_1 by using REG_MIS

Trip Rates (HBW_S) (MXD_REG_MIS)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.07	0.10	0.00	0.16	0.20
	2	0.00	0.00	0.00	0.09	0.13
	3	0.00	0.00	0.00	0.00	0.06
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
Two+ Workers	1	0.00	0.24	0.00	0.30	0.33
	2	0.00	0.00	0.20	1.50	0.00
	3	0.00	0.00	0.00	0.16	0.00
	4	0.00	0.00	0.00	0.10	0.13
	5	0.00	0.00	0.00	0.00	0.00

Table 23: Trip Rates for HBWC (Non-MXD) under S_1

Trip Rates (HBW_C) (Non-MXD)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.14	0.04	0.08	0.17	0.11
	2	0.26	0.17	0.07	0.00	0.00
	3	0.16	0.14	0.06	0.06	0.40
	4	0.33	0.07	0.21	0.21	0.08
	5	0.23	0.09	0.26	0.09	0.14
Two+ Workers	1	0.00	0.00	0.20	0.50	0.20
	2	0.00	0.27	0.19	0.14	0.11
	3	0.00	0.42	0.22	0.34	0.22
	4	0.00	0.45	0.23	0.43	0.13
	5	0.00	0.53	0.21	0.35	0.30

Table 24: Trip Rates for HBWC (MXD) under S_1 by using REG

Trip Rates (HBW_C) (MXD_REG)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.01	0.00	0.00	0.00	0.00
	2	0.19	0.02	0.00	0.00	0.00
	3	0.36	0.20	0.03	0.00	0.00
	4	0.54	0.37	0.21	0.04	0.00
	5	0.71	0.55	0.38	0.22	0.05
Two+ Workers	1	0.00	1.12	0.96	0.79	0.63
	2	0.00	1.30	1.13	0.97	0.80
	3	0.00	1.48	1.31	1.14	0.98
	4	0.00	1.65	1.49	1.32	1.15
	5	0.00	1.83	1.66	1.50	1.33

Table 25: Trip Rates for HBWC (MXD) under S_1 by using MEAN

Trip Rates (HBW_C) (MXD_MEAN)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.11	0.11	0.00	0.11	0.11
	2	0.25	0.00	0.00	0.11	0.11
	3	0.00	0.00	0.11	0.00	0.11
	4	0.00	0.11	0.11	0.11	0.11
	5	0.11	0.11	0.11	0.11	0.50
Two+ Workers	1	0.00	0.11	1.00	0.11	0.11
	2	0.00	0.50	0.11	1.00	1.00
	3	0.00	3.00	1.00	0.11	1.00
	4	0.00	1.00	0.75	0.11	0.11
	5	0.00	4.00	0.00	3.00	0.00

Table 26: Trip Rates for HBWC (MXD) under S_1 by using REG_MIS

Trip Rates (HBW_C) (MXD_REG_MIS)	Income	One	Two	Three	Four	Five+
Zero Worker	1	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
One Worker	1	0.01	0.00	0.00	0.00	0.00
	2	0.25	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.03	0.00	0.00
	4	0.00	0.37	0.21	0.04	0.00
	5	0.71	0.55	0.38	0.22	0.50
Two+ Workers	1	0.00	1.12	1.00	0.79	0.63
	2	0.00	0.50	1.13	1.00	1.00
	3	0.00	3.00	1.00	1.14	1.00
	4	0.00	1.00	0.75	1.32	1.15
	5	0.00	4.00	0.00	3.00	0.00

Table 27: Trip Rates for HBNWR (Non-MXD) under S_1

Trip Rates for HBNWR (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.00	0.03	0.00	0.00	0.00
2	0.08	0.16	0.04	0.15	0.00
3	0.11	0.26	0.04	0.19	0.15
4	0.13	0.11	0.04	0.26	0.11
5	0.12	0.26	0.07	0.02	0.06

Table 28: Trip Rates for HBNWR (MXD) under S_1 by using REG

Trip Rates for HBNWR (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	2.80	3.24	3.68	4.11	4.55
2	2.53	2.97	3.40	3.84	4.28
3	2.26	2.70	3.13	3.57	4.01
4	1.99	2.42	2.86	3.30	3.74
5	1.71	2.15	2.59	3.03	3.47

Table 29: Trip Rates for HBNWR (MXD) under S_1 by using MEAN

Trip Rates for HBNWR (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	2.00	3.00	5.33	1.54	8.50
2	1.54	1.54	1.33	1.54	1.54
3	0.33	1.54	1.54	1.00	2.00
4	1.50	3.00	3.75	1.54	1.54
5	4.00	4.00	0.50	6.00	1.50

Table 30: Trip Rates for HBNWR (MXD) under S_1 by using REG_MIS

Trip Rates for HBNWR (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	2.00	3.00	5.33	4.11	8.50
2	2.53	2.97	1.33	3.84	4.28
3	0.33	2.70	3.13	1.00	2.00
4	1.50	3.00	3.75	3.30	3.74
5	4.00	4.00	0.50	6.00	1.50

Table 31: Trip Rates for HBNWO (Non-MXD) under S_1

Trip Rates for HBNWO (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	1.03	1.94	2.74	3.85	5.43
2	0.89	1.73	2.14	3.64	6.16
3	0.70	1.74	1.83	3.53	5.97
4	0.62	1.51	2.22	3.45	7.42
5	0.81	1.21	2.49	5.07	7.24

Table 32: Trip Rates for HBNWO (MXD) under S_1 by using REG

Trip Rates for HBNWO (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.38	1.45	2.53	3.61	4.68
2	0.58	1.66	2.74	3.81	4.89
3	0.79	1.87	2.94	4.02	5.10
4	1.00	2.07	3.15	4.23	5.30
5	1.20	2.28	3.36	4.43	5.51

Table 33: Trip Rates for HBNWO (MXD) under S_1 by using MEAN

Trip Rates for HBNWO (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	2.00	3.50	0.00	3.00	3.50
2	1.14	2.00	2.33	0.00	4.00
3	1.00	2.00	0.00	12.00	4.00
4	0.50	0.83	3.00	3.00	3.00
5	0.00	0.00	3.50	0.00	12.00

Table 34: Trip Rates for HBNWO (MXD) under S_1 by using REG_MIS

Trip Rates for HBNWO (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	2.00	3.50	0.00	3.61	3.50
2	1.14	2.00	2.33	0.00	4.00
3	1.00	2.00	0.00	12.00	4.00
4	0.50	0.83	3.15	4.23	5.30
5	0.00	0.00	3.50	0.00	12.00

Table 35: Trip Rates for HBNWE1 (Non-MXD) under S_1

Trip Rates for HBNWE1 (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.00	0.08	0.89	2.23	3.57
2	0.00	0.04	0.90	2.18	4.03
3	0.00	0.06	0.70	2.27	3.03
4	0.00	0.02	0.76	2.31	3.06
5	0.00	0.02	0.81	2.18	3.39

Table 36: Trip Rates for HBNWE1 (MXD) under S_1 by using REG

Trip Rates for HBNWE1 (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.00	0.39	1.29	2.18	3.07
2	0.00	0.34	1.24	2.13	3.02
3	0.00	0.30	1.19	2.08	2.97
4	0.00	0.25	1.14	2.03	2.93
5	0.00	0.20	1.09	1.98	2.88

Table 37: Trip Rates for HBNWE1 (MXD) under S_1 by using MEAN

Trip Rates for HBNWE1 (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	1.30	3.00
2	0.00	0.40	0.67	2.00	5.00
3	0.00	0.00	1.00	3.00	2.00
4	0.00	0.00	0.00	1.30	1.30
5	0.00	0.00	0.50	0.00	5.00

Table 38: Trip Rates for HBNWE1 (MXD) under S_1 by using REG_MIS

Trip Rates for HBNWE1 (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	2.18	3.00
2	0.00	0.40	0.67	2.00	5.00
3	0.00	0.00	1.00	3.00	2.00
4	0.00	0.00	0.00	2.03	2.93
5	0.00	0.00	0.50	0.00	5.00

Table 39: Trip Rates for HBNWE2 (Non-MXD) under S_1

Trip Rates for HBNWE2 (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.05	0.13	0.30	0.08	0.10
2	0.00	0.01	0.12	0.00	0.06
3	0.06	0.03	0.17	0.02	0.13
4	0.00	0.06	0.00	0.12	0.11
5	0.00	0.02	0.10	0.17	0.13

Table 40: Trip Rates for HBNWE2 (MXD) under S_1 by using REG

Trip Rates for HBNWE2 (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.17	0.33	0.49	0.65	0.81
2	0.06	0.22	0.38	0.54	0.70
3	0.00	0.11	0.27	0.43	0.58
4	0.00	0.00	0.16	0.31	0.47
5	0.00	0.00	0.04	0.20	0.36

Table 41: Trip Rates for HBNWE2 (MXD) under S_1 by using MEAN

Trip Rates for HBNWE2 (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	0.09	3.50
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.33	0.00	0.00	0.00
4	0.00	0.67	0.25	0.09	0.09
5	0.00	0.00	0.50	0.00	0.00

Table 42: Trip Rates for HBNWE2 (MXD) under S_1 by using REG_MIS

Trip Rates for HBNWE2 (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	0.65	3.50
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.33	0.00	0.00	0.00
4	0.00	0.67	0.25	0.31	0.47
5	0.00	0.00	0.50	0.00	0.00

Table 43: Trip Rates for NWAIR (Non-MXD) under S_1

Trip Rates for NWAIR (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.00	0.04	0.00	0.00	0.00
2	0.00	0.01	0.00	0.10	0.00
3	0.04	0.00	0.02	0.00	0.00
4	0.05	0.00	0.00	0.05	0.06
5	0.00	0.04	0.11	0.12	0.00

Table 44: Trip Rates for NWAIR (MXD) under S_1 by using REG

Trip Rates for NWAIR (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.14	0.03	0.00	0.00	0.00
2	0.26	0.15	0.04	0.00	0.00
3	0.39	0.28	0.17	0.06	0.00
4	0.52	0.41	0.30	0.19	0.07
5	0.64	0.53	0.42	0.31	0.20

Table 45: Trip Rates for NWAIR (MXD) under S_1 by using MEAN

Trip Rates for NWAIR (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	0.03	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	1.00	0.00	0.00	0.00
4	0.00	0.67	0.00	0.03	0.03
5	2.00	0.00	0.50	0.00	0.00

Table 46: Trip Rates for NWAIR (MXD) under S_1 by using REG_MIS

Trip Rates for NWAIR (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	1.00	0.00	0.00	0.00
4	0.00	0.67	0.00	0.19	0.07
5	2.00	0.00	0.50	0.00	0.00

Table 47: Trip Rates for NHBW (Non-MXD) under S_1

Trip Rates for NHBW (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.09	0.17	0.30	0.77	0.40
2	0.27	0.54	0.50	0.44	0.55
3	0.38	0.60	0.64	1.24	0.97
4	0.57	0.61	1.07	1.29	1.58
5	1.13	1.04	1.51	1.37	2.22

Table 48: Trip Rates for NHBW (MXD) under S_1 by using REG

Trip Rates for NHBW (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.06	0.30	0.54	0.78	1.02
2	0.25	0.49	0.73	0.96	1.20
3	0.44	0.67	0.91	1.15	1.39
4	0.62	0.86	1.10	1.34	1.58
5	0.81	1.05	1.29	1.53	1.77

Table 49: Trip Rates for NHBW (MXD) under S_1 by using MEAN

Trip Rates for NHBW (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.67	0.81	0.00
2	0.71	1.60	0.67	2.00	3.00
3	0.33	0.33	0.00	0.00	0.00
4	0.00	0.33	2.00	0.81	0.81
5	0.00	2.00	2.00	2.00	1.50

Table 50: Trip Rates for NHBW (MXD) under S_1 by using REG_MIS

Trip Rates for NHBW (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.67	0.78	0.00
2	0.71	1.60	0.67	2.00	3.00
3	0.33	0.33	0.00	0.00	0.00
4	0.00	0.33	2.00	1.34	1.58
5	0.00	2.00	2.00	2.00	1.50

Table 51: Trip Rates for NHBO (Non-MXD) under S_1

Trip Rates for NHBO (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	1.00	1.05	2.37	1.85	1.93
2	0.91	1.27	0.96	1.13	2.29
3	0.72	1.09	1.04	1.41	3.41
4	0.86	1.36	1.20	1.95	4.58
5	0.75	1.15	1.81	3.18	4.83

Table 52: Trip Rates for NHBO (MXD) under S_1 by using REG

Trip Rates for NHBO (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.43	1.20	1.98	2.75	3.53
2	0.19	0.97	1.74	2.52	3.30
3	0.00	0.74	1.51	2.29	3.06
4	0.00	0.50	1.28	2.05	2.83
5	0.00	0.27	1.04	1.82	2.60

Table 53: Trip Rates for NHBO (MXD) under S_1 by using MEAN

Trip Rates for NHBO (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	0.40	1.00	0.00	1.75	9.00
2	0.14	0.60	0.00	0.00	0.00
3	1.00	0.00	0.00	7.00	4.00
4	0.50	1.00	2.00	1.75	1.75
5	1.00	0.00	0.50	0.00	2.00

Table 54: Trip Rates for NHBO (MXD) under S_1 by using REG_MIS

Trip Rates for NHBO (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	0.40	1.00	0.00	2.75	9.00
2	0.14	0.60	0.00	0.00	0.00
3	1.00	0.00	0.00	7.00	4.00
4	0.50	1.00	2.00	2.05	2.83
5	1.00	0.00	0.50	0.00	2.00

Table 55: Trip Rates for TRTX (Non-MXD) under S_1

Trip Rates for TRTX (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.16	0.23	0.30	0.62	0.70
2	0.04	0.17	0.08	0.28	0.00
3	0.19	0.07	0.17	0.08	0.41
4	0.00	0.07	0.05	0.05	0.33
5	0.00	0.12	0.14	0.13	0.15

Table 56: Trip Rates for TRTX (MXD) under S_1 by using REG

Trip Rates for TRTX (MXD_REG)					
Income	One	Two	Three	Four	Five+
1	0.33	0.31	0.29	0.27	0.26
2	0.25	0.24	0.22	0.20	0.18
3	0.18	0.17	0.15	0.13	0.11
4	0.11	0.09	0.08	0.06	0.04
5	0.04	0.02	0.00	0.00	0.00

Table 57: Trip Rates for TRTX (MXD) under S_1 by using MEAN

Trip Rates for TRTX (MXD_MEAN)					
Income	One	Two	Three	Four	Five+
1	0.40	0.50	0.67	0.18	0.00
2	0.00	0.00	1.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.50	0.18	0.18
5	0.00	0.00	0.25	0.00	0.00

Table 58: Trip Rates for TRTX (MXD) under S_1 by using REG_MIS

Trip Rates for TRTX (MXD_REG_MIS)					
Income	One	Two	Three	Four	Five+
1	0.40	0.50	0.67	0.27	0.00
2	0.00	0.00	1.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.50	0.06	0.04
5	0.00	0.00	0.25	0.00	0.00

Table 59: Trip Rates for EXTER (Non-MXD) under S_1

Trip Rates for EXTER (Non-MXD)					
Income	One	Two	Three	Four	Five+
1	0.00	0.03	0.00	0.00	0.00
2	0.09	0.16	0.04	0.15	0.00
3	0.11	0.27	0.04	0.20	0.16
4	0.14	0.11	0.05	0.26	0.11
5	0.13	0.26	0.07	0.02	0.07

Table 60: Trip Rates for EXTER (MXD) under S_1

Trip Rates for EXTER (MXD)					
Income	One	Two	Three	Four	Five+
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00

4.1.3 Trip Rates Summary

Despite limitation in sample size, the cross-tabulation shows interesting trip chaining patterns: MXD households make slightly more HBWD trips (average 1.507 person trips/household) than Non-MXD households (average 1.415 person trips/household), but much less HBWS trips (in average, 0.043 and 0.080 person trips/household in MXDs and non-MXDs, respectively). For HBWC, the average MXD trip chain rate (0.464 person trips/household) is much higher than that for Non-MXD (0.14 person trips/household). The variations may be attributed to the siting of schools and locations of community services. In MXDs, schools are relatively close to homes. School-age children are more likely to go to schools by themselves than those in non-MXDs. Similarly, stores, hospitals and other services tend to be more conveniently located in MXD neighborhoods than in non-MXDs. MXD residents thus are more likely to chain these activities with their commuting than non-MXD residents.

For HBNW, MXD residents make more retail trips than Non-MXD residents, likely due to more convenient access to retail shops that induce more trip making. In contrast, Non-MXD residents make more NHBO trips (1.66 person trips/household) than MXD residents (1.016 person trips/household). To understanding this difference, we may speculate that the Non-MXD residents live relatively farther away from service destinations and are thus more likely to perform NHB activities once they are away from homes.

4.2 FREQUENCY OF PRODUCED TRIPS

Once all trip rates were calculated, I applied those trip rate tables in the first step of 4-step travel demand model and calculated the frequency of produced trips as bellow. First, I compared the pros and cons of three methods for filling missing information in trip tables. Then I picked up the best-fit method and analyzed its result at the end of this section.

Table 61: Frequency of Produced Trips by using REG

Frequency of Produced Trips (REG)						
Trip purposes	Trip frequency for MXDs			Trip frequency for Non-MXDs		
	S_0	S_1	Difference (%)	S_0	S_1	Difference (%)
TOTAL	1134588	1621365	43%	4975183	190357	4%
HBWD	230213	332432	44%	1114689	155674	16%
HBWS	17408	11620	-33%	172530	64331	59%
HBWC	30099	127742	324%	116668	5763	5%
HBNWR	189542	360441	90%	708922	-15956	-2%
HBNWO	272632	327504	20%	1142320	-7970	-1%
HBNWE1	98203	124116	26%	482378	9490	2%
HBNWE2	9747	29309	201%	32155	-4397	-12%
NHBW	92333	103417	12%	444564	-10727	-2%
NHBO	160002	163823	2%	659983	588	0%

By using REG, too many trip rates were recalculated with regression method. Therefore when we looked at the trip rate tables, there are no huge difference of trip rates generated from different social-demographic conditions. But people may doubt about the reliability of this methods because too much information are manually changed and reset.

Table 62: Frequency of Produced Trips by using MEAN

Frequency of Produced Trips (MEAN)						
Trip purposes	Trip frequency for MXDs			Trip frequency for Non-MXDs		
	S_0	S_1	Difference (%)	S_0	S_1	Difference (%)
TOTAL	1134588	1205129	6%	4975183	190357	4%
HBWD	230213	224761	-2%	1114689	155674	16%
HBWS	17408	13140	-25%	172530	64331	59%
HBWC	30099	97882	225%	116668	5763	5%
HBNWR	189542	257167	36%	708922	-15956	-2%
HBNWO	272632	250388	-8%	1142320	-7970	-1%
HBNWE1	98203	73707	-25%	482378	9490	2%
HBNWE2	9747	16845	73%	32155	-4397	-12%
NHBW	92333	125606	36%	444564	-10727	-2%
NHBO	160002	92248	-42%	659983	588	0%

Different from REG, This method only estimated the trip rates for missing data. So it's more convincing from the perspective of statistic scholars. However, using regional average as the estimate for missing information definitely ignores the variance among different social-demographic conditions.

REG_MIS only recalculated the trip rates for missing data, but used the regression method which is different from MEAN. This method took the advantage of the other two methods as above. Therefore it is the best-fit method applied in estimating missing trip rates. For the result analysis, I only looked at the results by applying this method.

Note that S1 means I calculate trip rates for MXDs and Non-MXDs individually. In comparison with S0, generally, more trips are generated in MXDs than those in Non-

MXDs. Specifically, frequency of trips for HBWC, HBNWR and NHBW increase a lot in MXDs, while that for HBWD, HBWS and NHBO decrease a little bit.

Table 63: Frequency of Produced Trips by using REG_MIS

Frequency of Produced Trips (REG_MIS)						
Trip purposes	Trip frequency for MXDs			Trip frequency for Non-MXDs		
	S_0	S_1	Difference (%)	S_0	S_1	Difference (%)
TOTAL	1134588	1205129	6%	4975183	190357	4%
HBWD	230213	224761	-2%	1114689	155674	16%
HBWS	17408	13140	-25%	172530	64331	59%
HBWC	30099	97882	225%	116668	5763	5%
HBNWR	189542	257167	36%	708922	-15956	-2%
HBNWO	272632	250388	-8%	1142320	-7970	-1%
HBNWE1	98203	73707	-25%	482378	9490	2%
HBNWE2	9747	16845	73%	32155	-4397	-12%
NHBW	92333	125606	36%	444564	-10727	-2%
NHBO	160002	92248	-42%	659983	588	0%

4.3 TRIP NETWORK DISTANCE

The following table shows the trip network distances for people living in MXDs and those living in Non-MXDs.

Table 64: Trip Network Distance for People in MXDs and Non-MXDs

Trip Purposes	Home in MXDs				Home in Non-MXDs			
	Number	Distance (Miles)			Number	Distance (Miles)		
		Mean	Max	Std. Dev		Mean	Max	Std. Dev
Total	518	7.46	21.81	4.44	12405	8.25	28.55	5.34
HBWD	104	7.38	21.64	4.89	1826	7.99	27.13	5.16
HBWS	3	0.04	0.08	0.04	156	0.06	0.47	0.08
HBWC	6	8.47	15.08	4.88	204	7.70	23.26	5.28
HBNWR	101	5.69	16.71	3.98	1968	8.89	28.55	5.61
HBNWO	131	8.05	18.25	4.04	3451	8.38	28.31	5.28
HBNWE1	34	7.69	13.25	3.03	1285	8.48	25.74	5.31
HBNWE2	8	10.13	17.77	4.01	96	8.88	23.09	5.46
NWAIR	11	6.48	15.41	4.10	39	5.53	13.76	3.68
NHBW	51	8.57	21.81	5.54	1031	8.00	25.91	5.16
NHBO	59	8.14	19.58	3.65	2145	8.34	28.24	5.15
TRTX	10	8.72	17.59	6.08	204	8.72	26.39	5.21

On average, the network trips distances in MXD areas are about 0.8 miles shorter than those in NON_MXD areas. Especially, we can find this gap is enlarged for HBNWR (3.2 miles shorter). The possible reason is that people living in MXDs have more convenient access to retail uses. It accords with our expectation.

4.4 INTERNAL RATE OF CAPITAL

The table below reports internal rates of capture for each of the 42 MXDs in the study area.

Table 65: Internal Rate of Capital for Trips in MXDs and Non-MXDs

Variables	Trips in MXDs (n=1318)	Trips in Non-MXDs (n=11605)
Total Trips	1318	11605
Internal Trips	124	818
% Internal	9.41%	7.05%
By Purpose (% Internal)		
HBWD	8.91%	3.76%
HBWS	0.00%	2.67%
HBWC	0.00%	0.00%
HBNWR	6.25%	1.95%
HBNWO	5.46%	10.82%
HBNWE1	0.00%	11.81%
HBNWE2	13.33%	2.25%
NWAIR	0.00%	0.00%
NHBW	10.38%	3.67%
NHBO	17.46%	8.31%
TRTX	11.11%	8.02%

On average, 9.41% of MXD trips are internal, with both trip origins and destinations falling within identical MXD boundaries. This number is much higher than those in NON-MXD areas (7.05%). Specifically, the table also shows that MXDs absorb much more trips inside in terms of HBWD, HBNWR, HBNW2, NHBW and NHBO. It is demonstrated that more jobs, retail uses, schools, and services within MXDs make the need for external trips decreased a lot.

4.5 PERSON MILES TRAVELED

On average, a person living in MXDs travels 30 miles daily, about 1.2 miles less than those living outside MXDs. The difference between people living in MXDs and those in Non- MXDs, can be mainly attributed to shorter trips for HBNWR.

Table 66: Person Miles Traveled for People in MXDs and Non-MXDs

Trip Purposes	Home in MXDs				Home in Non-MXDs			
	Number	PMT (Miles)			Number	PMT (Miles)		
		Mean	Max	Std. Dev		Mean	Max	Std. Dev
Total	128	30.20	193.1	28.96	3258	31.43	378.9	30.36
HBWD	46	16.68	106.6	17.66	851	17.15	146.6	12.17
HBWS	1	0.12	NA	NA	52	0.18	0.6	0.18
HBWC	6	8.47	15.08	4.88	204	7.70	23.3	5.28
HBNWR	50	11.50	39.42	8.45	1117	15.62	95.9	12.90
HBNWO	52	20.28	93.99	16.31	1536	18.84	166.2	17.97
HBNWE1	19	13.76	26.42	6.44	719	15.16	47.9	10.20
HBNWE2	5	16.20	23.26	7.50	50	17.05	70.5	12.85
NWAIR	6	11.89	24.31	8.30	22	9.81	26.2	6.77
NHBW	24	18.22	54.69	13.62	472	17.42	359.2	24.32
NHBO	32	15.00	42.00	11.29	1069	16.67	131.6	16.38
TRTX	6	14.54	47.18	16.32	119	14.14	66.5	11.92

5. Conclusion

Land use planner, urban designer and transportation professions have had converging interest in the potential of altering urban form to alter travel outcome. Yet, when it comes to the implementation stage, there are a lot of barriers coming from both technical and non-technical aspects. This study focuses on the technical side and intend to integrate transportation planning and land use patterns. The research incorporated land use patterns and design metrics directly in the first three steps of the 4-step travel demand modeling procedures. The approach is illustrated through the Austin MSA, TX.

The study first identified MXD sites in the Austin, TX area and then analyzed travel characteristics associated with the MXDs vs. non-MXDs. Main results are summarized below:

1) Per CAMPO HBW classification, MXD households make slightly more HBWD trips than non-MXD households, but much less HBWS trips. For HBWC, the average MXD trip chain rate is much higher than that for non-MXD. For HBNW, MXD residents make more retail trips than Non-MXD residents, while Non-MXD residents make more NHBO trips (1.66 person trips/household) than MXD residents (1.016 person trips/household);
2) For frequency of produced trips, generally, more trips are generated in MXDs. Specifically, frequency of trips for HBWC, HBNWR and NHBW increase a lot in MXDs, while that for HBWD, HBWS and NHBO decrease a little bit;
3) On average, the network trips distances in MXD areas are about 0.8 mile shorter than those in NON_MXD areas. Especially, we can find this gap is enlarged for HBNWR (3.2 miles shorter);
4) For the internal rates of capture, 9.41% of MXD trips are internal, with both trip origins and destinations falling within identical MXD boundaries. This number is

much higher than those in NON-MXD areas. Specifically, MXDs absorb much more trips inside in terms of HBWD, HBNWR, HBNW2, NHBW and NHBO.

5) On average, a person living in MXDs travels 30 miles daily, about 1.2 miles less than those living outside MXDs. The difference between people living in MXDs and those in Non- MXDs, can be mainly attributed to shorter trips for HBNWR.

The results suggest areas in which CAMPO models can be modified or refined to capture the potential effects of the Activity Centers growth strategy on regional travel, for instance, revising trip rates for trip production and attraction modeling and improving estimation of internal trip making by including land use pattern indicators. Also, differences between MXD and Non-MXD in travel as reported above could have significant implications region wide.

Yet it should also be pointed out that fully incorporating the results in CAMPO planning process still requires additional efforts. For example, supplemental surveys of travel in the MXDs will be needed in order to apply this spatial grouping method. It is non-trivial task to accomplish what are suggested so far.

To conclude, the study contributes to transportation planning and policy making in Central Texas by providing local empirical evidence on land use pattern-travel indicator connection. The study's method and process can be of interest to a broad audience in academia and practice.

Appendix

SQL Coding for Classification of Trip Purposes:

```
SELECT * INTO Trip_D
FROM aussurvey06
WHERE Not ACTNUM=0
ORDER BY N_ID;
SELECT aussurvey06.* INTO Trip_O
FROM aussurvey06, Trip_D
WHERE aussurvey06.N_ID=Trip_D.N_ID-1;
SELECT * INTO Trip_Exter
FROM Trip_Total
WHERE O_LOCATION_1>5 OR D_LOCATION_1>5
ORDER BY TRIP_ID;
FROM Trip_Total
WHERE O_LOCATION_1<6 AND D_LOCATION_1<6
ORDER BY TRIP_ID;
SELECT DISTINCT PERSONID INTO People
FROM Trip_Inter
ORDER BY PERSONID;
SELECT * INTO People_HBW
FROM People
WHERE PERSONID IN
                                    ( SELECT PERSONID
                                      FROM Trip_Inter
                                      WHERE   O_PURPOSE=1   AND
(D_PURPOSE=3 OR D_PURPOSE=4)
                                      OR
```

(O_PURPOSE=3 OR O_PURPOSE=4) AND D_PURPOSE=1)

ORDER BY PERSONID;

SELECT Trip_Inter.* INTO Trip_HBW_Related

FROM Trip_Inter, People_HBW

WHERE Trip_Inter.PERSONID=People_HBW.PERSONID

ORDER BY TRIP_ID;

SELECT DISTINCT PERSONID INTO HBW_D1_1

FROM Trip_HBW_Related

WHERE O_PURPOSE=1 AND (D_PURPOSE=3 OR D_PURPOSE=4);

SELECT DISTINCT PERSONID INTO HBW_D1_2

FROM Trip_HBW_Related

WHERE (O_PURPOSE=3 OR O_PURPOSE=4) AND (D_PURPOSE=1);

SELECT DISTINCT v.PERSONID INTO HBW_D1

FROM HBW_D1_1 AS i INNER JOIN HBW_D1_2 AS v ON i.PERSONID=v.PERSONID;

SELECT Trip_HBW_Related.* INTO Trip_HBW_D1

FROM Trip_HBW_Related, HBW_D1

WHERE (Trip_HBW_Related.PERSONID = HBW_D1.PERSONID)

AND

((Trip_HBW_Related.O_PURPOSE=1 AND (Trip_HBW_Related.D_PURPOSE=3 OR Trip_HBW_Related.D_PURPOSE=4)) OR ((Trip_HBW_Related.O_PURPOSE=3 OR Trip_HBW_Related.O_PURPOSE=4) AND (Trip_HBW_Related.D_PURPOSE=1)))

ORDER BY TRIP_ID;

SELECT TRIP_ID, D_PURPOSE INTO HBW_D2_1A

FROM Trip_HBW_Related

WHERE TRIP_ID IN (SELECT TRIP_ID+1

FROM Trip_HBW_Related

```
WHERE (O_PURPOSE=1) AND (LESS5MIN_TR=1));
        SELECT DISTINCT TRIP_ID, PERSONID INTO HBW_D2_1
        FROM Trip_HBW_Related
        WHERE TRIP_ID IN (SELECT TRIP_ID
                                        FROM HBW_D2_1A
                                        WHERE D_PURPOSE=3 OR
D_PURPOSE=4);
        SELECT DISTINCT PERSONID INTO HBW_D2_2
        FROM Trip_HBW_Related
        WHERE (O_PURPOSE=3 OR O_PURPOSE=4) AND (D_PURPOSE=1);
        SELECT DISTINCT v.PERSONID INTO HBW_D2
        FROM HBW_D2_1 AS i INNER JOIN HBW_D2_2 AS v ON
i.PERSONID=v.PERSONID;
        SELECT DISTINCT Trip_HBW_Related.* INTO Trip_HBW_D2
        FROM Trip_HBW_Related, HBW_D2, HBW_D2_1
        WHERE (Trip_HBW_Related.PERSONID = HBW_D2.PERSONID)
                AND
                (((Trip_HBW_Related.O_PURPOSE=3 OR
Trip_HBW_Related.O_PURPOSE=4) AND (Trip_HBW_Related.D_PURPOSE=1))
                        OR
                Trip_HBW_Related.TRIP_ID=HBW_D2_1.TRIP_ID
                        OR
                 Trip_HBW_Related.TRIP_ID=HBW_D2_1.TRIP_ID-1)
                AND
                (NOT (Trip_HBW_Related.O_PURPOSE=4 AND
Trip_HBW_Related.D_PURPOSE=4 ));
        SELECT TRIP_ID, D_PURPOSE INTO HBW_D3_1A
        FROM Trip_HBW_Related
```

```
        WHERE TRIP_ID IN (SELECT TRIP_ID+1

FROM Trip_HBW_Related

WHERE (O_PURPOSE=3 OR O_PURPOSE=4) AND (LESS5MIN_TR=1));
        SELECT DISTINCT TRIP_ID, PERSONID INTO HBW_D3_1
        FROM Trip_HBW_Related
        WHERE TRIP_ID IN (SELECT TRIP_ID
                                        FROM HBW_D3_1A
                                        WHERE D_PURPOSE=1);
        SELECT DISTINCT PERSONID INTO HBW_D3_2
        FROM Trip_HBW_Related
        WHERE (D_PURPOSE=3 OR D_PURPOSE=4) AND (O_PURPOSE=1);

        SELECT DISTINCT v.PERSONID INTO HBW_D3
        FROM HBW_D3_1 AS i INNER JOIN HBW_D3_2 AS v ON
i.PERSONID=v.PERSONID;
        SELECT DISTINCT t3.* INTO Trip_HBW_D3
        FROM Trip_HBW_Related AS t3, HBW_D3 AS h3, HBW_D3_1 AS g3
        WHERE (t3.PERSONID = h3.PERSONID)
                        AND
                         (((t3.D_PURPOSE=3      OR      t3.D_PURPOSE=4)      AND
(t3.O_PURPOSE=1))
                                OR
                          t3.TRIP_ID=g3.TRIP_ID
                                OR
                          t3.TRIP_ID=g3.TRIP_ID-1)
                        AND
```

(NOT ((t3.O_PURPOSE=4 AND t3.D_PURPOSE=4) OR (t3.O_PURPOSE=3 AND t3.D_PURPOSE=4) OR (t3.O_PURPOSE=4 AND t3.D_PURPOSE=3)))

ORDER BY t3.TRIP_ID;

DELETE *

FROM Trip_HBW_D1

WHERE TRIP_ID IN (SELECT d1.TRIP_ID

FROM Trip_HBW_D1 d1, Trip_HBW_D2 d2, Trip_HBW_D3 d3

WHERE d1.TRIP_ID=d2.TRIP_ID OR d1.TRIP_ID=d3.TRIP_ID);

DELETE *

FROM Trip_HBW_D2

WHERE TRIP_ID IN (SELECT d2.TRIP_ID

FROM Trip_HBW_D2 d2, Trip_HBW_D3 d3

WHERE d2.TRIP_ID=d3.TRIP_ID);

SELECT DISTINCT * INTO Trip_HBW_D

FROM Trip_HBW_Related

WHERE TRIP_ID IN (SELECT DISTINCT TRIP_ID

FROM Trip_HBW_D1)

OR

TRIP_ID IN (SELECT DISTINCT TRIP_ID

FROM Trip_HBW_D2)

OR

TRIP_ID IN (SELECT DISTINCT TRIP_ID

FROM Trip_HBW_D3);

SELECT DISTINCT * INTO Trip_HBW_ND

```
        FROM Trip_HBW_Related
        WHERE TRIP_ID NOT IN (SELECT DISTINCT TRIP_ID
                                                FROM Trip_HBW_D);
        SELECT TRIP_ID, D_PURPOSE INTO HBW_S1_1A
        FROM Trip_HBW_ND
        WHERE TRIP_ID IN (SELECT TRIP_ID+1

FROM Trip_HBW_ND

WHERE (O_PURPOSE=1) AND (D_PURPOSE=10));
        SELECT DISTINCT TRIP_ID, PERSONID INTO HBW_S1_1
        FROM Trip_HBW_ND
        WHERE TRIP_ID IN (SELECT TRIP_ID
                                        FROM HBW_S1_1A
                                        WHERE   D_PURPOSE=3     OR
D_PURPOSE=4);
        SELECT DISTINCT PERSONID INTO HBW_S1_2
        FROM Trip_HBW_ND
        WHERE (O_PURPOSE=3 OR O_PURPOSE=4) AND (D_PURPOSE=1);
        SELECT DISTINCT TRIP_ID, PERSONID INTO HBW_S1_1
        FROM Trip_HBW_ND
        WHERE TRIP_ID IN (SELECT TRIP_ID
                                        FROM HBW_S1_1A
                                        WHERE   D_PURPOSE=3     OR
D_PURPOSE=4);
        SELECT DISTINCT Trip_HBW_ND.* INTO Trip_HBW_S1
        FROM Trip_HBW_ND, HBW_S1, HBW_S1_1
        WHERE (Trip_HBW_ND.PERSONID = HBW_S1.PERSONID)
                AND
```

```
                (((Trip_HBW_ND.O_PURPOSE=3 OR
Trip_HBW_ND.O_PURPOSE=4) AND (Trip_HBW_ND.D_PURPOSE=1))
                        OR
                Trip_HBW_ND.TRIP_ID=HBW_S1_1.TRIP_ID
                        OR
                 Trip_HBW_ND.TRIP_ID=HBW_S1_1.TRIP_ID-1);

        SELECT TRIP_ID, D_PURPOSE INTO HBW_S2_1A
        FROM Trip_HBW_ND
        WHERE TRIP_ID IN (SELECT TRIP_ID+1

FROM Trip_HBW_ND

WHERE (O_PURPOSE=3 OR O_PURPOSE=4) AND (D_PURPOSE=10));
        SELECT DISTINCT TRIP_ID, PERSONID INTO HBW_S2_1
        FROM Trip_HBW_ND
        WHERE TRIP_ID IN (SELECT TRIP_ID
                                FROM HBW_S2_1A
                                WHERE D_PURPOSE=1);
        SELECT DISTINCT PERSONID INTO HBW_S2_2
        FROM Trip_HBW_ND
        WHERE (D_PURPOSE=3 OR D_PURPOSE=4) AND (O_PURPOSE=1)
        SELECT DISTINCT v.PERSONID INTO HBW_S2
        FROM HBW_S2_1 AS i INNER JOIN HBW_S2_2 AS v ON
i.PERSONID=v.PERSONID;
        SELECT DISTINCT t3.* INTO Trip_HBW_S2
        FROM Trip_HBW_ND AS t3, HBW_S2 AS h3, HBW_S2_1 AS g3
        WHERE (t3.PERSONID = h3.PERSONID)
                AND
```

```
                    (((t3.D_PURPOSE=3 OR t3.D_PURPOSE=4) AND
(t3.O_PURPOSE=1))
                              OR
                     t3.TRIP_ID=g3.TRIP_ID
                              OR
                     t3.TRIP_ID=g3.TRIP_ID-1)
    ORDER BY t3.TRIP_ID;
    SELECT DISTINCT * INTO Trip_HBW_S
    FROM Trip_HBW_ND
    WHERE TRIP_ID IN (SELECT DISTINCT TRIP_ID
                                   FROM Trip_HBW_S1)
                OR
                TRIP_ID IN (SELECT DISTINCT TRIP_ID
                                   FROM Trip_HBW_S2);
    SELECT DISTINCT * INTO Trip_HBW_NDS
    FROM Trip_HBW_ND
    WHERE TRIP_ID NOT IN (SELECT DISTINCT TRIP_ID
                                        FROM Trip_HBW_S);
    SELECT * INTO Trip_HBW_C
    FROM Trip_HBW_NDS
    WHERE (O_PURPOSE=1 AND (D_PURPOSE=3 OR D_PURPOSE=4 )) OR
(D_PURPOSE=1 AND (O_PURPOSE=3 OR O_PURPOSE=4 ));
    SELECT DISTINCT * INTO Trip_N_HBW
    FROM Trip_Inter
    WHERE TRIP_ID NOT IN (SELECT DISTINCT TRIP_ID
                                        FROM Trip_HBW_D)
                AND
                TRIP_ID NOT IN (SELECT DISTINCT TRIP_ID
                                        FROM Trip_HBW_S)
```

```
                    AND
                    TRIP_ID NOT IN (SELECT DISTINCT TRIP_ID
                                                    FROM Trip_HBW_C);
    SELECT DISTINCT * INTO Trip_HBNW_R
    FROM Trip_N_HBW
    WHERE (O_PURPOSE=1 AND D_PURPOSE=7) OR (O_PURPOSE=7 AND
D_PURPOSE=1);
    SELECT DISTINCT * INTO Trip_NHBW_NR
    FROM Trip_N_HBW
    WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                                FROM Trip_HBNW_R);
    SELECT DISTINCT * INTO Trip_HBNW_E1
    FROM Trip_NHBW_NR
    WHERE (O_PURPOSE=1 AND D_PURPOSE=5) OR (O_PURPOSE=5 AND
D_PURPOSE=1);
    SELECT DISTINCT * INTO Trip_NHBW_NRE1
    FROM Trip_NHBW_NR
    WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                                FROM Trip_HBNW_E1);
    SELECT DISTINCT * INTO Trip_HBNW_E2
    FROM Trip_NHBW_NRE1
    WHERE (O_PURPOSE=1 AND D_PURPOSE=6) OR (O_PURPOSE=6 AND
D_PURPOSE=1);

    SELECT DISTINCT * INTO Trip_NHBW_NRE
    FROM Trip_NHBW_NRE1
    WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                                FROM Trip_HBNW_E2);
    SELECT DISTINCT * INTO Trip_NW_AIR
```

```
FROM Trip_NHBW_NRE
WHERE (O_TYPE_OF_PL=21 OR D_TYPE_OF_PL=21) AND (NOT O_PURPOSE=3) AND (NOT O_PURPOSE=4) AND (NOT D_PURPOSE=3) AND (NOT D_PURPOSE=4);
SELECT DISTINCT * INTO Trip_NHBW_NREA
FROM Trip_NHBW_NRE
WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                      FROM Trip_NW_AIR);
SELECT DISTINCT * INTO Trip_HBNW_O
FROM Trip_NHBW_NREA
WHERE O_PURPOSE=1 OR D_PURPOSE=1;
SELECT DISTINCT * INTO Trip_NHB
FROM Trip_NHBW_NREA
WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                      FROM Trip_HBNW_O);
SELECT DISTINCT * INTO Trip_NHB_W
FROM Trip_NHB
WHERE O_PURPOSE=3 OR D_PURPOSE=3 OR D_PURPOSE=4 OR O_PURPOSE=4;

SELECT DISTINCT * INTO Trip_NHB_NW
FROM Trip_NHB
WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                      FROM Trip_NHB_W);
SELECT DISTINCT * INTO Trip_TRTX
FROM Trip_NHB_NW
WHERE O_MODE=8 OR O_MODE=9 OR O_MODE=12 OR D_MODE=8 OR D_MODE=9 OR D_MODE=12;
SELECT DISTINCT * INTO Trip_NHB_O
```

```
FROM Trip_NHB_NW
WHERE TRIP_ID NOT IN (SELECT TRIP_ID
                      FROM Trip_TRTX);
```

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