The Impacts of Land Use and Urban Form on Travel Behavior.

A parcel-level destination-choice model for shopping travel in South-East Florida.

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Abstract:

The coordination between land use and transportation has been the focus of several research studies. Land use and transportation research identify the relationship between land use and transportation as being bi-directional: the impact of transportation on land use (captured via the accessibility measure); and the impact of land use on transportation (captured via land-use descriptors such as diversity, density, design, destinations and distance). The focus of this research is on the latter effect. In this context, discrete-choice models have been used to capture the effect of traveler demographics, transportation-network and other spatial variables on the choice of destinations for various trip purposes. However, many of these studies have focused on modeling destination choices at the coarser spatial resolution of Traffic Analysis Zones (TAZs) and have incorporated relatively fewer land-use descriptors in their models.

The main purpose of this paper is to study the impact of land use and urban form on destination choice for shopping activities using discrete choice models. Land parcels will be used as the spatial resolution of the destination choices. The research will employ the regional travel survey data from Southeast Florida (Miami-Dade, Broward, and Palm Beach Counties) and very detailed parcel level land use data from the region. Several land use and urban form indices will be used including the density, land use mix, accessibility, connectivity and distance.

Introduction:

Great efforts have been conducted in the coordination between land use and transportation which have two directions. The first direction is the Impact of transportation on land use. There has been lack of research that works to capture this impact because of the difficulty to measure land use change in short intervals of time. Furthermore, the indicators of such study are extremely flexible. Most of the studies that deal with the impact of transportation on land use are trying to measure the accessibility which has a wide range of definitions. Researchers use these definitions of accessibility in forecasting land use changes, growth patterns and future land uses.

The other direction is the land use impact on transportation and travel behavior. This direction is very well covered in the research. Most of the research concentrates on measuring the urban form and its relation to the travel behavior. Ewing and Cervero (2001) summarized most of the literature on the effect of land use on transportation through taking the research performed on density, diversity, design, destination and distance and their impact on travel behavior.

The bi-directional research covers the land use impact on travel distance, travel time or mode choice and not destination choice. However, destination choice models have been also used to connect the spatial pattern to the travel behavior and traveler demographic characteristic (Pozsgay & Bhat, 2001) but included few spatial measures and performed on aggregate transportation analysis zone (TAZ) level. The studies in the bi-directional land use transportation coordination were also performed on an aggregate level of analysis using Traffic Analysis Zones (TAZ) or urban form neighborhoods as defined areal units. This paper will use a parcel level destination choice model that uses more spatial explanatory variables to capture the impact of land use and urban form on the travel decision of where to shop. The paper will also use disaggregate measures of accessibly, connectivity and travel distance in addition to land use mix and density.

Coordinating Land Use and Transportation Literature Review:

Considering the land use impact on transportation, one of the most important research conducted in the area captures, what is called the 3D's, which are the density, diversity and design and their effect on travel behavior. Cervero and Kockelman (1997) used the 1990 travel diary and land use records for San Francisco bay area and worked on non-work trips to show that built environment affects the travel miles travelled per household and modal choice. Their research showed that the density, land use diversity or land use mix in addition to the pedestrian oriented design reduce the trip rate and encourage walking and transit use. They also emphasized that compact development affects modal choice. For the design element the study shows that the grid network and restricted parking reduce the use of autos and increase the use of transit and walking. Frank and Pivo,1994) empirically study the effects of land use mix, population density and employment density on the use of single occupant vehicles, transit use and walking in addition to the modal choice. In this research the land use mix is measured at the trip ends and the study showed that walking and the transit use increase with increasing the density and land use mix while the use of the single occupancy vehicles decreases. The research also shows that measuring land use mix at the trip ends gives a greater ability to predict modal choices. In addition to that, increasing the density and land use mix at the trip end also increase the walking and transit use and reduces the use of the single occupancy vehicles.

Cervero and Radisch (1996) as well as Handy (1996) studied the pedestrian activity. For Cervero and Radisch they found that the modal choices for bike and pedestrian increases in a transit oriented neighborhood. The same result was obtained by Handy and that is the urban form affects the modal choice and increasing the local accessibility will increase the people's choices of where to go locally by walking, biking, transit or driving and that leads to increase the modal choices for people.

Ewing and Cervero (2001) added two additional variables to the 3D's; these additional variables are destinations (accessibility) and distance (distance to major transit stops). Litman (2008) investigates land use accessibility by the potential destinations within a geographic area. This accessibility is increased with the increase of population density and that, reduces the travel distance and the need for automobiles, therefore, decreasing the modal choice of driving. Furthermore, increasing the density will also increase the transportation options but at the same time decrease the speed and increase the congestion.

In terms of measurement methodologies for diversity and land use mix, Cervero and Kockelman (1997) used the entropy and dissimilarity indices which capture the land use mix and heterogeneity in a neighborhood, in addition to, the density and design variables in a regression analysis to find the impact on transportation through modal choice and VMT. The entropy and dissimilarity are indices that are calculated on a neighborhood scale to capture the land use mix. The entropy measure in general takes the percentages of the land use mixes in the neighborhood to build the index. For the entropy index, this index was developed by Frank & Pivo (1994) to describe the evenness of the distribution of built square footage among seven land-use categories.

For the dissimilarity index, it was developed by Cervero & Kockelman (1997) to capture the land use mix. This index was based on the dissimilarity of a hectare use from the adjacent eight hectares that surround that specific hectare. The average of hectare accumulations across all active hectares in a tract is the dissimilarity which is an indication of the land use mix in that tract. The significance of such indices was covered by the TCRP (2003) report which showed that land use diversity is the most significant factor in increasing walkability and reduces the use of automobiles. It also suggested that, accessibility and entropy are the most efficient in capturing the travel behavior.

Considering the transportation impact on land use, most of the research in the area addressed an accessibility type of measure. However, the measurement of accessibility varied between research, going from linear distance to network distance, travel time and the number of activities within a distance from an attraction or a certain residential location. Accessibility can be defined as the potential to interact, and to differentiate between the accessibility and mobility. We can say that the mobility is the potential to move. In these terms, accessibility is connected to destinations and the mobility is connected to the networks and vehicles. Accessibility for example, measures the number of jobs in a certain area or the number of destinations in a specified area or the availability of choices between modes, while the mobility deals with traffic delay and level of service (Handy, 2004).

Accessibility measurement can also be divided to personal accessibility or place accessibility. The personal accessibility can be measured by counting the number of activities within a certain distance of person home and the measurement can also include the magnitude of the distance for each location in a gravity cumulative approach. The accessibility for a place which investigates the number of activities at a certain distance from a place can also be measured in the same way (Hanson, 2004).

Distance measures are also different in research where some land use researches use the Euclidian distance as a base, other researches use the network distance as the base. Using network distance can be obtained by measuring the actual distance travelled or the time of travel. The use of the travel time may be more sophisticated and take additional variables into consideration. Arafat et al (2007) compared the network distance to the Euclidean distance in a school sitting research and found that the use of network distance gives a better estimation for the walking distance than the Euclidean distance and the catchment areas for population which is an accessibility indicator is exaggerated using and Euclidean buffer.

The common research on accessibility is based on aggregate analysis zones. However, it is more helpful to go to the parcel level especially when capturing the traveler's choices. Disaggregate and parcel level research can reduce the shortcomings of the traditional models in capturing the fine land use effect on transportation or vice versa (Lee, 2004). Johnston (2004) mentioned that future land use and transportation modeling should be discrete in both time and location and based on GIS tract or street address. This shows the common ground for the latest and future land use and transportation modeling. The same GIS approach has been recommended by Wegner (2005) to deal with the disaggregate data in addition to the new trend in transportation modeling which is the activity based models.

The aforementioned research on the impact of transportation on land use suggested the significance of accessibility. As the wide range of accessibility definitions we can realize that it can be a measurement of the distance opportunities, attraction or interaction between them which is also dependent on the network characteristic. This is also suggest that the same variables such as attraction, accessibility and connectivity have interactive impacts on destination choice and transportation network as well as the need for parcel level disaggregate analysis.

Researchers argued the applicability of the four step modeling in transportation. In these models, generating the production of the trips is generally depend on household characteristics such as income, gender, number of people in the household, number of cars, etc. and depending on household surveys for the number of trip without taking urban form or network characteristics into account. In addition to that, in trip- based model such as the four step model, the time of day is not scheduled and thus ignored. The use of time in the four step model is limited to certain uses in decided the peak count. The four step models also does not take into account the interdependence between trip and it divide the trips as home and non home based trips and thus there is no distinction between a single stop home based journey and a multiple stop journey (Bhat and Koppelman,1993).

The bidirectional land use transportation research proves that land use characteristics do not only effect the travel distance but also affect the number of generated trips (Ewing and Cervero, 2001). This shows more flaws in the steps of the four step model and that the land use impact is beyond the trip distribution step represented by gravity models. In land use models like UrbanSIM a modified five step model is used to replace the four step model. This five step model accounts for the interaction between the transportation modeler and the land use. This fifth step uses density and transit accessibility measures as a feedback loop between trip distribution and network assignment (Waddell, 2002).

The deficiencies in the four step modeling leads to more flexible approach such as the discrete choice models. Steed and Bhat (2000) used discrete choice models to study the preference of age groups for recreational trips and found that the choice of the elderly person is different from the choice of the general population giving importance to differences in age groups in the choice models. However they mentioned that the time of the day in the travel behavior if scheduled can solve the problem of congestion.

Poszgay and Bhat (2001) investigate the urban recreational trips in an attraction end destination choice model which relates the demographic characteristics and end attraction and level of service of data in study that has implication on air quality and land use planning.

Researchers established the use of discrete choice models in transportation modeling which includes the land use as an end attraction on destination choice models. Research studies have been performed on the impact of urban forms on transportation and the impact of accessibility on land use change. However, in the conducted research, only few spatial attributes are used in discrete choice models. This paper will use more spatial variables using more disaggregate level analysis. The study will use the travel diary for south East Florida as well as the demographic data, land use data, network characteristics, and built environment variables in a destination choice model.

Research Methodology:

1. **Model Structure:**

The proposed model is an elemental destination choice model which will assign each shopping parcel as a destination alternative. So we can represent the model in the following Matrix form.

$$U = \beta^T * T + \gamma^T * O + \delta^T * D + \alpha^T * X$$

Where N is the group of trip characteristics, O is the group of origin characteristics, D is the destination characteristics, X is the group of variables generated from trip distance interacted with different demographic variables.

1. **Trip Characteristics:**

The available trip characteristics are specified as the travel distance and the trip circuity. The travel distance is calculated by the shortest distance approach from each origin to all destinations using network analysis. The connectivity or the circuity index is also calculated using an origin-destination based approach and captures the network connectivity for a certain origin destination combination. However, this index is based on the circuitry values (El-Geneidy & Levinson, 2007). The circuity value is defined as the ratio of the network to the Euclidean distance.

A GIS parcel level analysis model was created for the distance and circuity calculation. The model generates a parcel level origin-destination matrix and calculates the network distance for each origin to each destination. The Euclidian distance and the circuity values are also calculated using the parcel level origin destination matrix.

2. Origin Characteristics:

Researchers found that increasing density, local accessibility and land use mix affect the mode choice and the distance traveled (Ewing and Cervero, 2001; Handy, 2004). If we investigate these variables we can see that increasing the origin density will promote other modes of transportation like biking and transit. The same can be said about accessibility because increasing the number of opportunities around an origin will promote for shorter trips and reduce the probability of choosing further destinations.

This paper will investigate the significance of the origin density, origin land use mix (entropy) and origin accessibility to destinations as variables for origin characteristics. The methodology for calculating the density and land use mix are based on a 2.5 mile by 2.5 mile roving neighborhood around each point of interest to represent the surrounding neighborhood. Figure 1 shows the gross density raster based on these neighborhoods.

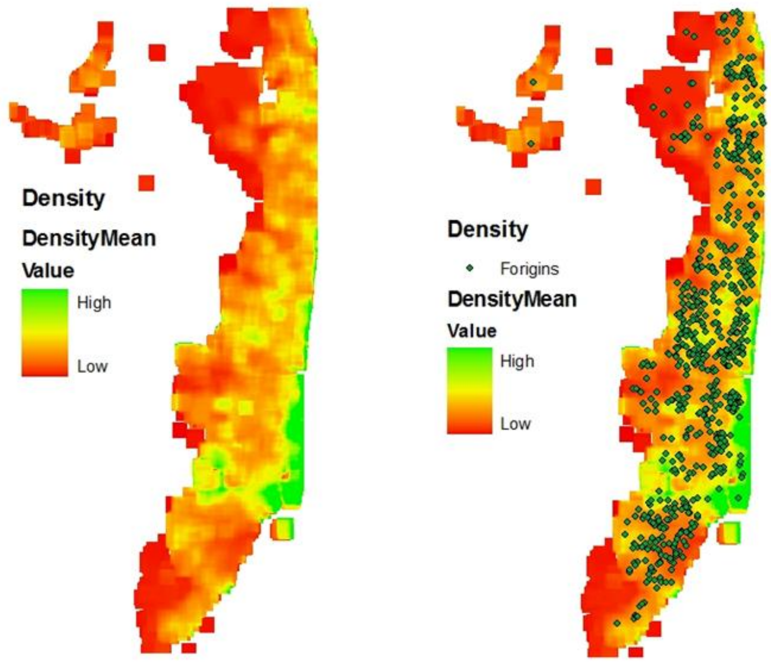


Figure 1: Density and Trip origin distribution

From figure 1 we can see that the distributions of shopping trip origins are mainly in the medium density. Therefore, low variations in the density values may decrease the impact of density in the final model. The calculations of the Entropy values are performed using the same areal unit. The values are calculated according to Frank & Pivo (1994) methodology and applied to five different land uses categorized as residential, retail, service, industrial and “other” category. The following equation shows how the entropy value is calculated:

$$Entropy = \left\{ \sum_{k} \left[(p_i)(\ln p_i) \right] \right\} / (\ln k)$$

Where,

p_i is the proportion of used in each land use category.

k the total number of land use categories.

The raster in figure 2 shows the entropy values for the study area as well as the origin distribution. From the figure shows that the trip origins are mainly in location with high to medium land use mixes in the surrounding neighborhood.

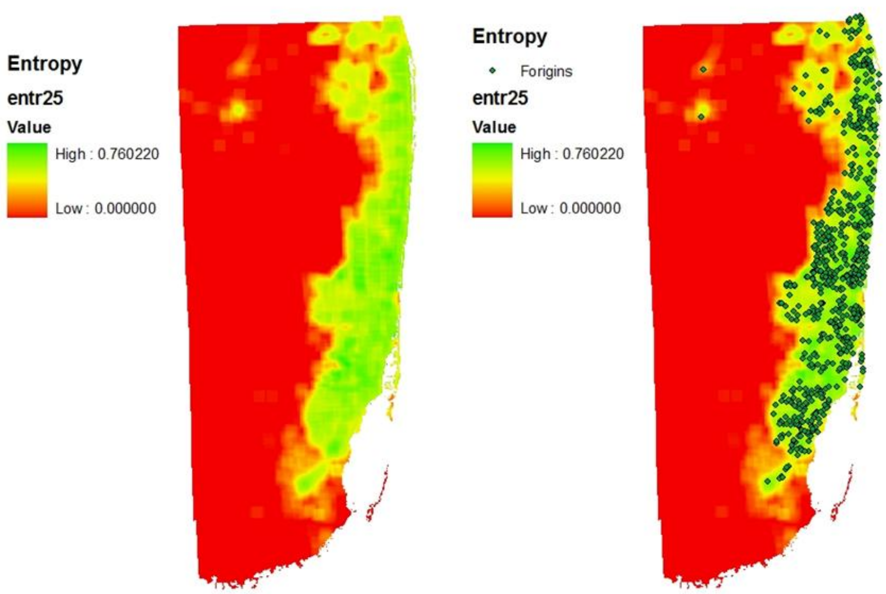


Figure 2: Entropy Values and origin distribution

The methodology for calculating the accessibility is a model that will contain all the destinations and their network distances aggregated to the origin parcel. This index were calculated according to the following equation proposed by Bhat et al (2002) where they proposed different equations for calculating the accessibility indices.

$$A_i = LN\left[\frac{1}{J}\sum_{J}\frac{O_j}{d_{ij}^{\alpha}}\right]$$

Where (A_i) is the accessibility index; (I) is the origin number; (j) is the destination number; (d_{ij}) is the distance between the origin to each destination; (α) is the distance decay factor.

The final origin variable that is used is the opportunity accessibility which is defined as the cumulative area of retail and shopping opportunities within the neighborhood. However, the areal unit or the neighborhood is defined as a roving neighborhood with every parcel as a center of the neighborhood used to capture the surrounding for that parcel. Therefore, the value of the opportunity access varies from each parcel to the other.

3. Destination Characteristics:

The choice of destination according to the gravity model depends on the characteristics of destinations in terms of destination attractiveness. The attractiveness of destination depends on the floor area ratio and acreages which also an indication of commercial density. This measure is independent from the origin accessibility because the origin accessibility is an aggregate measure of attractiveness to destinations while this measure is a characteristic for each destination. In the destination choice model, attraction is taken in logarithmic form because it is a size variable and to be consistent with the gravity trip distribution model. The choice of destination also may depend on the Competition Ratio (Relative Importance) variable which is calculated according to the following equation (Daly, 1980):

$$RI_{ik} = LN\left[\sum_{J} \frac{O_k d_{ik}^{\alpha}}{O_j d_{ij}^{\alpha}}\right]$$

As a connectivity indicator, a new variable is added to the model which is the relative circuity. This variable is calculated by dividing the destination circuity which is measured from one origin to one destination over the summation of all the circuity values from that origin to all destinations.

4. Demographic characteristics:

Since it is difficult to explore the effect of the demographic characteristics on the location choice using statistical analysis programs such as SPSS, preliminary data exploration is performed by looking at the frequencies of the chosen trips. For example, the number of employees and the number of children variables are dropped because of the high percentage of missing data in the travel survey. Other variables will be used in the model and their significance will be determined by the logit models using NLOGIT program. However, these demographic variables are not used directly in the utility functions used in this study. These variables are interacted with the trip distance by dividing the trip distance over each of the used demographic characteristics. The following explanatory variable is to be tested on logit models: (Trip Distance / household size), (Trip Distance / number of license drivers), (Trip Distance / number of vehicles) and (Trip Distance / income of the household).

Generation of the choice sets:

The universal choice set will be all the parcel identified as commercial or retail in the land use data. To limit the number of alternatives in the study, a randomly drawn subset of 50 alternatives (destinations) for each origin including the chosen alternative is generated. To do that, a new GIS tool was created to randomly draw the 50 destination out of whole universal set of retail parcels. The alternatives should be identically and independently distributed (IID) which is assumed by the random choice of alternatives.

Descriptive Statistics:

The data was sample was obtained from randomly drawing of fifty alternatives including the chosen alternative from the origin destination matrix that contain approximately 17 million records which is generated from all the reported origins in the travel survey to more than 17500 different destination choices. The origin destination matrix was obtained using ArcGIS Network Analyst. However, the alternatives were generated by a random selection of features using a customized GIS tool developed for that purpose. The following table shows the general statistics on the data sample.

Variable	Count
Number of cases	891
Number of Alternatives	50
Total Number of data records	44550

The Data sample contains a randomly chosen set of fifty alternatives for each origin. Each randomly chosen destination in the 50 alternatives represents 350 destinations in the universal dataset. The following table shows some descriptive statistics of the data sample

Variable	Mean	Std.Dev.	Minimum	Maximum
Network Distance (miles)	33.16	20.69	0.0	106.55
Attraction (SQF)	17801.23	85703.23	0.0	2127143.00
Circuitry	1.33	0.25	1.00	4.37
Entropy	0.54	0.72	0.22	0.75

Results and discussion:

The area of study is composed of three counties (Miami-Dade, Broward, and Palm Beach Counties). Using the random data set, different models had been estimated in an iterative procedure by adding one variable at a time and comparing the Rho^2_{adjust} value. A summary of the estimation likelihood and Rho^2_{adjust} is shown in the following table

Table 1: Estimation of A – K Models (Data set 1)

Variables	Likelihood at convergence	Rho^2_{adjust}
Base Models		
Model A: No Coefficients	-3485.6125	
Model B: Network Distance	-1954.9138	.43913
Model C: Network Distance and Attraction (gravity spec.)	-1753.9542	.49678
Model D: Adding Competition Ratio	-1746.3743	.49894
Model D: Adding Relative Circuity	-1744.3022	.49952
Model D: Adding Accessibility	-1744.0348	.49959
Model E: Adding Density, Entropy, Household size, Number of License Driver, Number of Vehicles and House hold Income.	-1734.9112	.50214
Dropping Statically Insignificant Variables		
Model F: Dropping Relative Circuity (t = -.981)	-1736.8724	.50159
Model G: Dropping Accessibility (t = 1.015)	-1737.3410	.50147
Model H: Dropping Density (t = -.896)	-1737.7814	.50135
Model I: Dropping Household size and Number of License Drivers(t= 1.535 and t = -1.567)	-1739.4774	.50089

After analyzing the models for variable significance using the t test, Chai- squared test and Rho^2_{adjust} value, it was found that the best model to represent the data is Model (I). The following table shows the parameter estimation for that model. Variables such as density were found insignificant at 90% confidence. Therefore, this paper will not discuss the impact of these variables. Furthermore, only two household characteristics were significant in the model. These variables are the distance per vehicle and distance per different income range.

Another important comparison was performed between the gravity model (B) and the best model (I) and it was found that the specification (I) is better than the gravity model. This gives us a hint on the trip distribution step in the four step modeling procedure. If model (I) is applied for trip distribution it gives better result if than the gravity model used in the trip distribution step in the four step modeling. The equation for the trip distribution for model (I) will be:

$$T_{ij} = O_i \frac{e^{V_{ij}}}{\sum_j e^{V_{ij}}}$$

Where (T_{ij}) is the number of trips between (i) and (j), (O_i) is the number of shopping trips from Parcel (i) and (V_{ij}) is the utility of choosing destination (j) for parcel (i). However, the utility in this model includes more variables than the distance and attraction specified in the gravity utility equation which can be stated as:

$$U_{GRAVITYij} = D_{ij} + \text{Log}\ (\text{attraction}_j)$$

The estimation for model (I) parameters is shown in the following table.

Table 2: Estimation for model (I) parameters

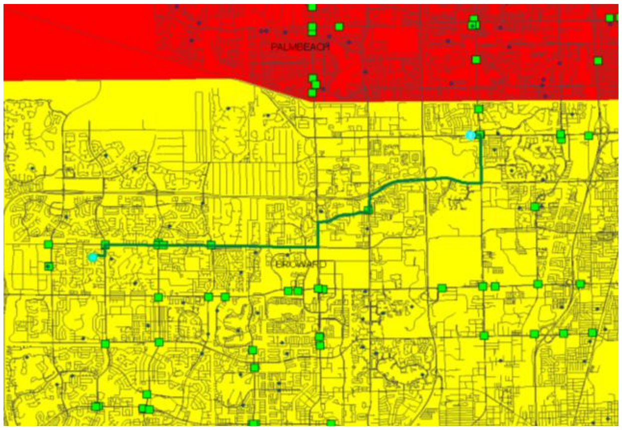
Variable	**Parameter**	**t-statistic**
Destination Characteristics		
Log (attraction)	.4736	18.344
Competition Ratio	8.7238	2.760
Trip Characteristics		
Network Distance	-.3681	-9.906
Network distance/Origin Characteristics		
Entropy (land use mix)	.0553	3.676
Network distance/ Traveler Characteristics		
Number of Vehicles	.0684	2.241
Income	-.1790	-1.744
Log-likelihood at convergence		-1739.4774
Log-likelihood for no coefficients		-3485.6125
R- Square		.50096
R- Square Adjust		.50089
Observations		891
Bad Observations		0

The best model shows the significance of the Distance, Competition Ratio, Attraction, Land use mix, Distance per vehicle and Distance per different income ranges in determining the destination of where to shop. However, other estimated models show the impact of density, relative circuity and house hold size but these variables where not included because they have no statistical significance at 90% confidence interval and thus neglected.

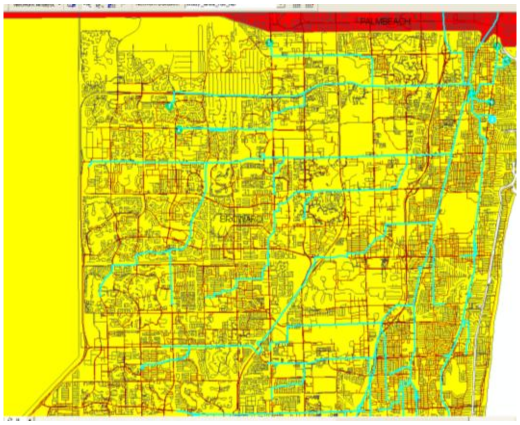
Interpretation of the results:

1. **Network Distance:**

The negative coefficient for the distance variable shows that increasing the network distance will decrease the probability of choosing the destination. Therefore, the results indicate that people prefer to shop in places that are nearer to their home residence and this result is in agreement with the land use-transportation coordination literature. However, people do not depend only on distance in determining where to shop. Figure 4a shows a randomly selected trip from the chosen alternatives, this trip clearly emphasize that the commuter have many nearer shopping alternatives but he chose the further one. Figure 5b shows many trip alternatives for a commuter. Some of these trips have long distances and others have short distances.



A) Chosen trip (Green squares are shopping Designations



A) Trip Alternatives (Cyan lines)

Figure 5: Chosen and alternative routes

2. **Attraction:**

This measure is defined as the Logarithm of the attraction area of a destination. The positive coefficient for the attraction variable shows that increasing the attraction increases the probability for choosing the destination which is in agreement with the gravity trip distribution models.

3. **Accessibility to Shopping Destination and Competition Ratio:**

Accessibility is defined as the potential attractions for the origin inversely weighted by the distance and aggregated to the origin. The competition ratio is defined as the accessibility for a certain alternative divided over the origin accessibility to all destinations. This variable is used to interpret the effect of origin accessibility to destination. Increasing origin accessibility will increase overall negative coefficient for the distance and decrease the overall negative coefficient for the attraction. Therefore people are more likely to choose closer destination or larger attractions if the origin accessibility is increased. This also means that planning for shopping opportunity within neighborhoods will decrease the distance, increase the attraction and increase the origin accessibility and finally, according to model (I), the probability of choosing the neighborhood destinations will increase.

4. **Entropy and Land use mix:**

The entropy value represents how much land use mix in the neighborhoods. However, this paper uses a roving neighborhood of size 2.5 x 2.5 mile around each parcel and therefore the entropy value will vary on a parcel level. Model (I) shows that increasing the value of entropy and keeping other variables constant will increase the overall negative model coefficient for the network distance and thus increase the probability of choosing closer destinations.

5. **Traveler characteristics:**

The household characteristics that were significant in the models are the number of vehicles and the household income. The parameter of distance divided by the income shows that people with higher income are less sensitive to travel distance and thus may choose destination that are further and they tend to travel more to do their shopping. However, the household number of vehicles does not show the same relationship. It seems that for the household in the travel survey, if the family has more vehicles does not mean they travel more. On the contrary, the model shows that people with more vehicles are more sensitive to travel distance and therefore may choose closer destinations.

Research Implications:

In terms of transportation models, the trip distribution in the four step modeling is performed according to the gravity models which mainly include the zonal pair distances and a measure of attraction such as retail floor area. The results of this research show that the proposed model is better than a gravity model. However, it does not contradict with the gravity model in terms of the impact of distance and attractions. The gravity model is usually applied on zonal pairs and does not capture the zonal internal trips which are important to understand congestion problems. The research disaggregation level includes the parcel to parcel distance and urban form measurements that are not covered by the gravity trip distribution model. Furthermore the gravity model does not include any household characteristics while the best model in this research includes the number of vehicles for the household and the household income.

In terms of the transportation and land use planning, the results suggest the importance of accessibility, attraction, land use mix and distance on our decision of where to shop. For distance and accessibility, the model shows clearly that people prefer to shop in places that are nearer to their place of residence. Therefore, creating new shopping facilities or increasing shopping attractiveness within or close to neighborhood, decreases the travel distance and make people choose these nearer destinations instead of traveling to further destinations. The same can be said about the in the land use mix variable. Adding local shopping opportunities in the neighborhoods will increase the land use mix entropy value and thus therefore people will be more likely to choose a closer destination or higher attractiveness. Adopting such land use policies will decrease in the shopping travel distance which is an important factor in reducing traffic congestion and improving air quality.

Summary and Conclusions:

The results show that distance, attraction, accessibility represented by competition ratio, land use mix, number of vehicles per household and household income impact the choice of shopping destinations. The results also suggest that people are most likely to shop in places that are nearer to their place of residence. The results do not contradict with the impact of the attraction on the choice which is a basic element of the gravity model. However, it is not difficult to conclude that the result agrees with the trend towards more compact development as suggested by most of the transportation studies in different bi-directional land use and transportation coordination research. The results are also important for the efforts to reduce congestion and air quality problems. However, the transportation models such as the four step models do not include the impact of land use on transportation or the traveler characteristics which make it lacks the ability to solve these problems. Using disaggregate destination choice models gives more emphasis for better handling these problems.

Destination choice models have incorporated some spatial measures such as attractions but these models were limited to aggregate spatial resolutions. This research has incorporated more land use variables on a disaggregate parcel level destination choice model and shows that distance, attraction, accessibility, land use mix, number of vehicles per household and household income are significant and they impact the choice of the shopping trips while density and connectivity (relative circuity) were found insignificant at 90% confidence interval. However, this does not mean that the impact of density and circuity should not be included. Testing other intermediate destination choice models show that density and connectivity have impact on the destination choice but these variables where insignificant in the final model.

The final model results suggest the destination choice model is better than a gravity model trip distribution model as it includes more explanatory variables and have better goodness of fit. However, the research has been performed for shopping trips, therefore, the results does not represent other types of trips. More research is needed on other trip categories such as work and entertainment trips

The research had undergone certain limitations in terms of the data, research methods and analysis. In terms of data, the number of shopping trips is limited to 894 trips and the travel survey has a lot of missing data for household characteristics. Excluding missing data means decreasing the number of trips. However many household characteristics is excluded because of the missing data. In terms of methods, the research uses disaggregate approach for parcel level and that is applied on measuring the network distance, connectivity and access. However, the measurement of density and entropy are prepared using roving neighborhoods and thus their values vary across parcels. Furthermore, many of the urban form measurements depend on aggregation for certain neighborhood sizes. Coming up with disaggregate urban form measurements is beyond the scope of this paper and will be left for future research.

In terms of the analysis, the preparation of the model was performed on NLOGIT software which has limitations on the number of alternatives. Therefore, the research is performed on 50 alternatives. More representative results could be obtained using other software and that will be performed in future research.

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