THE CREATION OF A MODEL TO ESTIMATE THE CHANGE IN NON-MOTORIZED TRANSPORTATION USE AFTER A LAND USE CHANGE

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ABSTRACT

THE CREATION OF A MODEL TO ESTIMATE THE CHANGE IN NON-MOTORIZED TRANSPORTATION USE AFTER A LAND USE CHANGE

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Studies have shown that an increase in non-motorized transportation (NMT) has been linked to healthy benefits such as an increase in physical activity, lower body mass index, and a decreasing chance of developing a chronic disease. New theories of economic development, such as Placemaking, have also emphasized increasing NMT. However, there is no tool to quantify the changes in NMT ability before and after a development. This project develops such a modeling tool and applies it to the City Center II development in East Lansing, MI. A literature review identifies built environment variables that explain the variance in American Community Survey walking, biking, and riding the bus to work data. After conducting correlations with the means to work and built environmental data, the final variables are used in a linear regression, along with socio-economic controls. A service area is created utilizing ArcGIS's Network Analyst tool to define an area ½ mile around the development. Derived regression coefficients are applied to the service area in order to estimate the pre-development amount of people who took NMT to work. The anticipated final redevelopment project is then reproduced in ArcGIS and the service area is recreated. The same regression coefficient formula is applied to the new service area and the result is the estimated number of people who will take NMT to work post-development. The results show that the development will increase the amount of people who take NMT to work from 28.58% to 30.68%. Finally, the benefits and policy implications of using a model to assess the change in NMT use before and after a land use is discussed.

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LIST OF ABBREVIATIONS

ACS – American Community Survey

CIAA - Corridor Improvement Authority Act

GIS – Geographic Information System

MACIA - Michigan Avenue Corridor Improvement Authority

MSA – Metropolitan Statistical Area

NMT – Non-Motorized Transportation

PLT – Path, Lanes and Trails

SES – Socio-Economic Status

TAZ – Transportation Analysis Zone

TCRPC – Tri-County Regional Planning Commission

VTPI – Victoria Transportation Policy Institute

CHAPTER 1

INTRODUCTION

1.1 Background of Transportation Modeling

Today, decision makers rely on a spectrum of modeling tools in order to make transportation decisions. For example, every federally designated metropolitan planning organization employs some sort of transportation forecasting model (Hardy, 2011). The problem with these modeling systems is that very few look at the transportation and land use system in an integrated way and non-motorized transportation (NMT) is rarely included in these models (Hardy, 2011; Rodriguez & Joo, 2004).

The relationship between land use and transportation has been studied for over 50 years, but little understanding exists about how the built environment influences travel behavior (Frank et al., 2008). Many planners understand that conceptually and intuitively, a transportation/land use connection exists and should be addressed at all levels of transportation and land-use planning; however, they lack information on exactly how that connection works and how it can be measured (Moore & Thorsnes, 2007).

Research has shown that there is a connection between the built environment and which mode of transportation an individual will take (Abdul et al., 2007; Chen et al., 2008). This influence has also shown to extend to an individual’s choice of taking NMT (Winters et al., 2010; Killingsworth et al., 2003; Belanger, 2010; Handy et al., 2006; Soltani et al., 2006). However, there has also been a growing amount of research that suggests people will self-select areas that encourage NMT to live in, so the built environment will not influence walking or biking more, but it will attract those who like to take those modes of transportation (Handy et al., 2006). In any case, the built environment has a role in being able to predict which mode of transportation an individual will take.

Issues including, but not limited to, lack of reliable data, computational power, or knowledge of non-motorized travel behavior have hampered modeling NMT for metropolitan areas (Iacono et al., 2010). Despite the lack of understanding, the federal government still spent $3.17 billion on 10,012 bicycle- and pedestrian-related projects for states and counties, between 1992 and 2004 (Cradock et al., 2009).

In 2009, researchers looked at the 10,012 projects from 1992 and 2004 and came up with three policy recommendations for improving public health with federal grants, one of which was to show an explicit link between transportation and public health (Cradock et al., 2009). This can be accomplished through quantifying the change in non-motorized transportation after land use changes. However, the transportation modeling world has been slow to include these variables in their forecasting. This paper aims to fill the gap in understanding and predicting the connection between land use change and its effects on NMT.

This paper develops a model that is used to estimate the number of people who currently take NMT to work and thenestimates the amount of people who take NMT to work after a land use change. The example land use change is a proposed mixed-use development in downtown East Lansing, Michigan – City Center II. The creation of such a model has other benefits than acquiring federal grant money, including:

1. Local officials can use this model as a marketing tool to show citizens how a project will increase the NMT ability of an area.
2. Developers are able to calculate the improvements in NMT a development will create in order to help obtain more public funding.

3. Citizens are able to identify how walkable/bikable an area is post-development prior to project completion, which would enable them to reserve a unit sooner.

1.2 Benefits of Non-motorized Transportation

There is evidence that non-motorized transportation is associated with economic development. From a local government standpoint, walkability increases property values; it is cheaper to build and maintain sidewalks and bicycle parking facilities than it is to build and maintain roads and parking lots/structures; and pedestrian infrastructure projects have a higher employment multiplier than other transportation projects (Pivo & Fisher, 2011; Litman, 2009; Garrett-Peltier, 2011).

There are also personal economic benefits for users of NMT. Costs for such things as parking, vehicle maintenance, and fuel can be reduced through taking NMT to work (Litman, 2009). In addition, other overlooked or undervalued benefits arise when taking NMT. For instance, it is less expensive to ride a bike for exercise than to join a health club, and one is less likely to obtain a traffic violation, among other benefits (Litman, 2011).

Researchers have also found that non-motorized transportation is also linked to such health benefits as a lower body mass index (Konikov-Titievsky, 2010; Lovasi et al., 2009; Berry et al., 2010) and a lower risk of developing a chronic disease (Stone & Gostin, 2003). In addition, the mental health and social benefits of the reduced isolation from living in a walkable community can help raise the quality of life and the social capital of an individual (Leyden, 2003; Wood et al., 2010; Rogers et al., 2011).

Non-motorized transportation has differing benefits for differing cohort groups. Specifically, walking is a very valuable health tool for senior citizens. For seniors, walking is a way to lower blood sugar, reduce body fat, lower blood pressure, improve bone density, and keep good mental health (Witt, 2010). Research has shown that in addition to personal, social, and organizational related factors, the built environment plays an important role in inhibiting senior participation in physical activity (Li et al., 2005; Joseph, 2006; King, 2006). The senior citizen population – those over 65 years old – increased by 15.1% in the United States between 2000 and 2010, and it is estimated to more than double between 2010 and 2050 (Administration on Aging, 2010). Therefore, it is more important than ever for communities to make sure that the built environment encourages walking and does not impede it.

From a theoretical standpoint, non-motorized transportation is also a key asset in Placemaking. The process and result of making a place with unique features that people want to use, be in, enjoy and/or remember, because it was interesting or pleasurable, is called Placemaking (About 21c3). According to the Center for 21st Century Communities, there are eight key assets which are critical to making a vibrant community, two of which are physical design &walkability and transit. Placemaking is key to job creating and retaining knowledgeable workers in the New Economy (Wyckoff, 2010). Therefore, non-motorized transportation is also an important element in future economic development.

1.3 Non-motorized Transportation Variables

Non-motorized transportation typically includes walking, biking, and variants such as small-wheeled transport and wheelchair travel (VTPI, 2010). However, a growing body of research shows that taking public transit will have the same health, environmental and economically beneficial uses as walking and biking (Maghelal, 2011; Litman, 2012). This has led some researchers to expand their definition of NMT to include public transit (Appleyard, 2010; Neiman, 2010).

Researchers have derived many ways to calculate the influence of the built environment on people's ability to walk, ride a bike, or take public transportation. This section will look into the variables most commonly included and the methods used.

Densities, diversity of land uses, and the design of streets and transit systems are commonly assembled to create a walkability index (Lovasi et al., 2011). Perhaps the first well known study to attempt to quantify walkability was the 1000 Friends of Oregon 1993 report, Making the Land Use, Transportation, Air Quality Connection. The variables chosen to analyze walkability were ease of street crossings, sidewalk continuity, local street characteristics (grid vs. cul-de-sac), and topography (1000 Friends of Oregon, 1993).

Since the 1993 Friends of Oregon report, there have been many variations of the elements that go into a NMT index or predictive models. The walkability index consisting of net residential density, retail floor area ratio, intersection density, and land-use mix created by Lawrence Frank from the University of British Columbia. has become the most common calculation for walkability (Frank et al., 2006; Frank et al., 2007; duToit et al., 2007; Leslie, et al., 2007; Owen et al., 2007; Frank et al., 2008; Gebel, 2009; Marshall et al., 2009; Sallis et al., 2009; Frank et al., 2010). Other researchers have used this model but did not include the retail floor area ratio because of a lack of resources (Sundquist et al., 2011; de Sa, 2011).

There are indices or models whose variables are chosen because of the availability of information/data, and Frank et al. (2010) acknowledges that using the four elements previously mentioned is sometimes out of necessity and not proven by research:

"Although many other variables have been hypothesized and in some cases shown to be related to active transport such as sidewalks, traffic calming and intersection characteristics, those variables are not widely available in existing datasets, so the present four-component index represents a practical starting point and improved versions can be developed as conceptualization and data availability improve."

There are examples of NMT models and indexes that use other variables. Table 1 provides an overview of these variables. Each of these variables has a multitude of ways to calculate them.

Table 1 Non-Motorized Transportation Variables

Built Environment Variable	**Reference**
Public Transportation	Lovasi et al., 2009; Konikov-Titievsky, 2010; Seeley, 2005; Forsyth et al., 2008;
Employee Density	Maghelal, 2011; Forsyth et al., 2008; Kim, 2006
Mixed-land use	de Sa, 2011; Forsyth et al., 2008; Kim, 2005; Konikov-Titievsky, 2010; Lovasi, 2006; Lovasi et al., 2009; Ozbil et al., 2008; Song et al., 2007
Park Access	Lovasi, 2006; Forsyth et al., 2008;
Population Density	Konikov-Titievsky, 2010; Lovasi et al., 2009; Kim, 2005;
Presence of Sidewalks	Harkey et al., 1998; Lovasi, 2006; Maghelal, 2011; Seeley, 2005; Lovasi et al., 2009; Forsyth et al., 2008
Street Connectivity	du Toit et al., 2007; Forsyth et al., 2008; de Sa, 2011; Maghelal, 2011; Ozbil et al., 2008; Song et al., 2008

According to the Victoria Transport Policy Institute, connectivity "refers to the density of connections in path or road network and the directness of links…Connectivity can apply both internally (streets within that area) and externally (connections with arterials and other neighborhoods).” With the advent of geographic information systems (GIS) in the 1990’s, street pattern has been more commonly used as a measure of walkability (Forsyth et al., 2008). There are many different ways to calculate connectivity, including block length, block size, block density, intersection density, street density, connected node ratio, link-node ratio, grid pattern pedestrian route directness, and effective walking area (Dill, 2004; Tresidder, 2005). Nearly all NMT models include at least one component of street connectivity.

Mixed-land use is defined as the level of integration within a given area of different types of uses for physical use (Konikov-Titievsky, 2010). Land use mix, especially the close proximity of shopping, employment and food to residential areas is shown to be related to greater walking and cycling among residents (Saelens et al., 2003; Mouden et al., 2006).

Similar to street connectivity, researchers have found many ways to calculate land-use mix. For example, Frank et al., (2010) created an entropy score, which consisted of five land uses: residential, retail, (excluding “big box” stores), entertainment (including restaurants), office, and institutional (including schools and community institutions). The amount of land cover per census tract was calculated and then normalized between 0 and 1, with 0 being a single use and 1 indicating a complete even distribution of floor area between the five uses.

Other examples of calculations for mixed-land use include taking the percentage of total parcel area in different land uses and applying those unique ratios to the model (Forsyth et al., 2008). Resources such as Walkscore.com use destination based analysis in order to calculate land-use mix. Walk score uses an algorithm to create a single score based on the distance to such destinations as restaurants, parks, post offices, hospitals, shopping centers, bars, grocery stores, etc. (Walk Score, 2011).

1.4 Travel Distances

Researchers have created predictive models and indexes for a variety of study areas. The size of the study area varies greatly from large places such as TAZs, neighborhoods, census block groups, zip codes to smaller areas like ½ and ¼ mile buffers and 1 km buffers. However, spatial units, such as census block groups, can be too large to capture the variations in urban form that occur at a much smaller scale (Frank et al., 2007). A 1-kilometer (0.6 mi) buffer created along a road network is the distance that can be covered in a ten-minute walk (Frank et al., 2007). Therefore, a smaller buffer, one that is in non-motorized transportation traveling distance to the study area is the best choice for analysis.

The average distance traveled by destination walking and bicycling varies slightly. In a study conducted in Montreal, Canada the median walking distance was 650 meters (0.4 miles) and the average distance traveled by bicycle was two kilometers (1.2 miles) with a high degree of variation (Larsen et al., 2010). In 1999, the Wisconsin Survey research Laboratory conducted a Bicycle and Pedestrian Survey. They found that the most common distance traveled by walking was between ½ mile and a mile; the most common distance traveled by bicycle was between ¼ and ½ mile each way.

The average distance walking to transportation is very similar to that of walking and biking to any other destination. In a case study conducted at the Mountain View, California public transportation station area, people walked 0.43 miles from the north and 0.65 miles from the south to the transit stop (Park, 2008). In an Atlanta, GA study the median distance traveled to a transit station was 0.47 miles (Ozbil, 2010). O'Sullivan (1996) found that the average walking distances to suburban bus stations was 0.4 miles and the average distance walked to central business district bus stops was 0.2 miles, in Calgary.

The selection of a network or circular buffer has a considerable influence on the results of a project (Oliver at al., 2007). A circular buffer, commonly known as 'straight-line' or 'as-the-crow-flies', can include disconnected areas in the calculation of a service area. A network buffer is created along pathways that are accessible from the study location; therefore, network buffers are more of a reflection of the NMT area that a person can cover. One method for calculating a network buffer is to use the Network Analyst Extension in ArcView, where the size of the buffer varies based on the connectivity of the road network – more intersections allow a greater area to be covered on the ground (Frank et al., 2007).

1.5 Non-motorized Transportation Variable Selection

Several aspects of social-economic status (SES), including educational attainment and income have been shown to contribute to an individuals' amount of physical activity (Cerin et al., 2009). Physical characteristics of the neighborhood environment, access to recreational activities, perceived safety and security are all potential reasons for the discrepancy in resident's SES and their neighborhood's walkability (Cerin & Leslie, 2008; Edwards & Tsouros, 2006). Other researchers have also discovered a link between incomes and built environmental variables that influence walking. For example, higher income neighborhoods experience greater park use which results in higher income individuals walking more – this is because high-SES residents have access to parks with higher levels of safety, maintenance and attractiveness (Leslie et al., 2010).

Researchers have commonly used controls in their predictive models in order to isolate the influence that the built environment has on walkability/bikability. Some of the more common examples of controlled variables include: income, sex, age, educational attainment, ethnicity, and car availability (Owen et al., 2007; Maghelal, 2011; Kim, 2005).

In regard to commuting to work, higher salary income and more expensive housing is associated with a greater propensity to working from home, but a lower propensity of walking or biking to work. College education in most cases is associated with taking NMT to work. Lastly, other variables such as car ownership, race, and gender are shown to influence the likelihood of taking NMT to work, but the results have sharp differences across sub-regions within metropolitan areas (Plaut, 2005).

A shortcoming of current methods to quantify NMT is that they utilize all variables at their disposal without checking if those variables contribute to increasing NMT or if they have multicollinearity. For example, Lovasi et al, (2009) included population density and bus access in their walkability index. Although, it would seem likely that bus stops are placed in pockets of high population density. In addition, most of the projects focus on one aspect of NMT, although, all three have the same positive benefits.

The above research studies and the variables identified were used to select the current study potential variable list. Including the destination based variables: bus stop density, employee density, population density, commercial property density, park/school density, and household density, three connectivity variables (connected node ratio, intersection density, and effective walking area) and two land use variables (path, lane, and trail density, and sidewalk presence) were selected to be included in the predictive model. Table 2 has a brief description of the measure, definition and data source used to calculate the variables.

Table 2 Non-Motorized Transportation Variables

	Measure	Definition	Data source
Connectivity	Connected node ratio	Ratio of real nodes (intersections with three or more legs) to total nodes	Node shapefile created by Mark Jones using all roads file from TCRPC*
	Intersection density	Ratio of real nodes per acre	Node shapefile created by Mark Jones using all roads file from TCRPC
	Effective walking area	Ratio of parcels per acre	TCRPC
Destination	Employee density	Employees per acre	TCRPC
	Bus stop density	Bus stops per acre	TCRPC shapefile obtained from Capital Area Transportation Authority
	Population density	Population per acre	2005-2009 ACS**
	Household density	Ratio of households per acre	2005-2009 ACS
	Commercial property density	Acres that are zoned commercial divided by total acres	TCRPC generalized zoning file
	Park and school density	Ratio of land area for parks, elementary schools, middle schools, high schools, and MSU's main campus (acres) to the land area (acres).	TCRPC
Land Use	Sidewalk presence	Ratio of sidewalk length (ft.) to road length (ft.)	Tri-County Regional Planning Commission (TCRPC) all roads and sidewalks file
	Path, lane, and trail density	The average length of bike trails, widened shoulders, walking trails, and bike lanes (ft.) per acre	TCRPC

* Tri-County Regional Planning Commission
** American Community Survey

CHAPTER 2

APPLICATION

The City Center II proposed project is at the intersection of Michigan Avenue and West Grand River Avenue, in East Lansing, MI. The $105 million, 5.25-acre project includes a ten-story, mixed-use building, which will consist of residential units, retail, restaurant and office space and a 400-seat performing arts theater. One block to the north of the 10 story structure will be a five-story, mixed-use building with retail and a restaurant on the first floor and residential units on the upper floors. Also, the project includes a parking garage, a four-story residential building, and nine (9) townhouses (City of East Lansing, 2012).

The City Center II project is just one of many developments and rehabilitations occurring along the Michigan/Grand River corridor since the creation of the Michigan Avenue Corridor Improvement Authority (MACIA). The MACIA was created by the 2005 Corridor Improvement Authority Act (CIAA), P.A. 280 of 2005, and amended in 2007. The CIAA provides for the creation of a public economic development corporation that will work to “correct and prevent deterioration in business districts, encourage historic preservation, promote economic growth” (Michigan Ave Corridor, 2011).

The Act allows multiple municipalities to collaborate and establish one unified authority with jurisdiction over the entire corridor. The authorities can create broad initiatives, but they must include three things: allow for mixed use and high density residential, expedite permitting, and support non-motorized transportation. The partners in MACIA include the City of Lansing, City of East Lansing, Lansing Township, and Michigan State University. According to the Michigan Avenue Corridor Improvement Authority website:

> “The ultimate goal of the project is to revitalize and beautify the Michigan Avenue corridor to make it more walkable, attract a larger base of customers and create a pleasant living environment for surrounding neighbors.”

With the City Center II project being constructed under this setting, it would imply that the project will increase the amount of people who take non-motorized transportation. However, there is no tool at the disposal of the Authority which can estimate the change in the amount of people who take non-motorized transportation after a development. This study develops such as tool and applies it to the City Center project to assess the effects of development on NMT.

CHAPTER 3

METHODS

The 2005-2009 American Community Survey (ACS) means to work data – walking, biking and public transportation - for all 117 census tracts within the Lansing tri-county metropolitan area (Ingham, Eaton & Clinton Counties) is used as the dependant variable in the NMT model. The eleven (11) variables in Table 3 are selected from the literature review and the values are calculated per census tract, and are the independent variables.

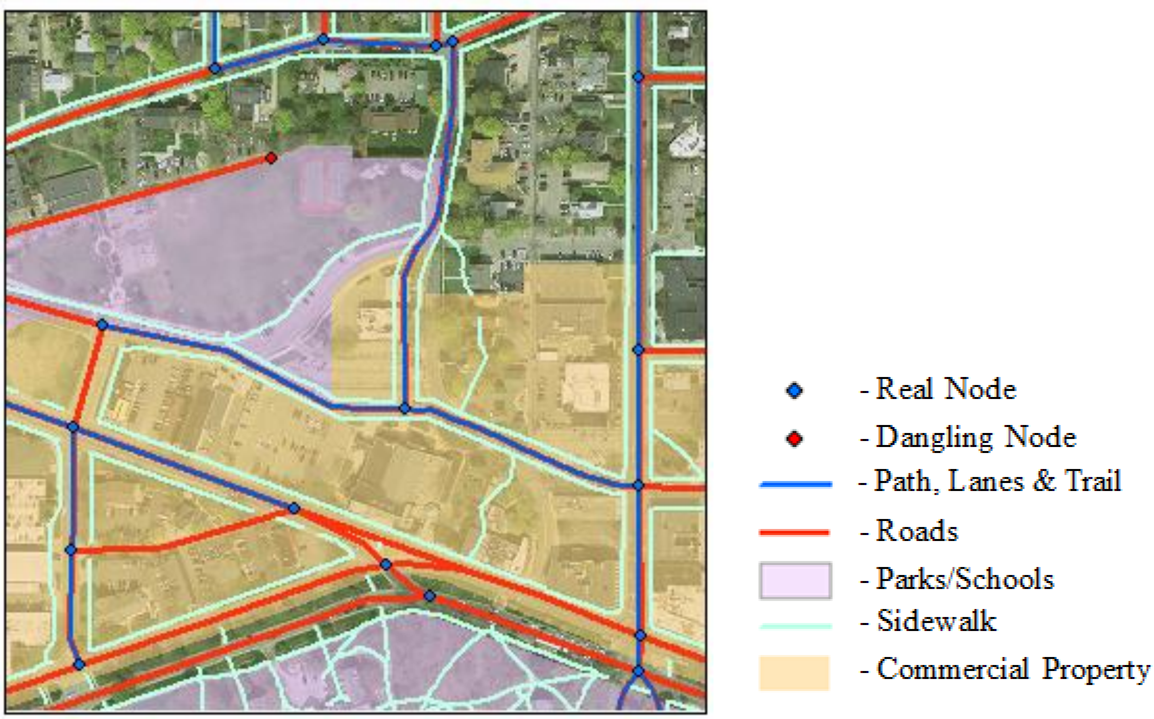
Utilizing ArcGIS, the NMT variables are calculated per census tract in order to run correlations. The sidewalk presence, path, lane, and trail density, commercial property density, and park and school density variables are calculated using the Intersect tool. The connected node ratio, bus stop density, employee density, and intersection density are calculated using the Spatial Join tool. Finally, the population density and household density values are calculated using data gathered from the 2005-2009 ACS website.

A one-half mile service area is created around the current structures in the development region. The service area is created using ArcGIS's network analysis tool and by placing facilities around the perimeter of the project area. The resulting service areas are merged into one shapefile resulting in the pre-development NMT service area.

The plans used for site plan review for the City Center II proposal were obtained from the City of East Lansing website, and are used for the post development measurements for the current NMT model. Using these plans, the physical environment changes are duplicated in ArcGIS (Figure 1). A new service area is created using the new built environment characteristics and a final shapefile is created called the post-developed NMT service area (Figure 2).

Figure 1 Pre-Development

Figure 2 Post-Development



For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

The same ArcGIS tools are utilized to calculate the eight built environment values in the pre- and post-development service areas. However, the population density is more difficult to determine. The service areas are over laid with 2010 TIGER/Line shapefile block data. The blocks that the service areas covered are included in the population density calculation. The final pre-development value of 12.75 people/acre is the sum of the blocks that the service area covered (580.77 acres) divided by the 2010 population of those blocks (7,403).

Currently, where the proposed development will occur, there are three vacant buildings owned by the City of East Lansing and six residences with 59 occupants (Mullins, 2012). The City Center II development will contain three (3) one-bedroom units, one-hundred and three (103) two-bedroom units, and sixteen (16) three-bedroom units. Assuming that there will be full occupancy, the development will increase the population by sixty-three (63).

Finally, the derived regression coefficients in the full model are applied to the pre- and post-development service areas and their built environment variable values. The results are then compared in order to estimate the change in the amount of people who take NMT to work after the construction of City Center II.

CHAPTER 4

RESULTS

All variables are texted to identify in any multicollinearity exits. Any variable that demonstrates multicollinearity is eliminated from consideration. Household density, effective walking area and bus stop density are subsequently eliminated because of multicollinearity, leaving eight variables to be included in the model(s) (See Appendix A for correlations). The control variables selected were based on data availability from the ACS. Per-capita income[1], median age, ethnicity[2], gender[3], and educational attainment[4] data for all Lansing tri-county census tracts are correlated. Per-capita income and median age are found to have a correlated value of 0.7352; therefore, median age was eliminated. Ethnicity and education were found not to be significant when inserted into the predictive models, so those control variables were also left out. The final control variables left in the model were per-capita income and gender. The final model, with control variables and without, is displayed in Table 3.

[1] Per-capita income in the past 12 months (in 2009 inflation-adjusted dollars)
[2] Percent of “white only” population
[3] Percent male
[4] Percent of population with an Associate’s, Bachelor’s, Master’s, or Professional Degree

Table 3 Regression Outputs
(See Appendix B & C for full regression outputs)

	Model w/o SES Controls	**Full Model**
Income		-3.992E-6*** (-2.003)
Gender		0.367* (1.742)
Intercept	-0.237** (-2.568)	-0.271** (-2.003)
Population density	0.009** (2.277)	0.003 (0.730)
Path, lane, and trail density	0.003*** (3.759)	0.003*** (4.669)
Sidewalk ratio	0.056*** (2.734)	0.046** (2.341)
Commercial property density	0.179 (1.588)	0.153 (1.444)
Real node ratio	0.297** (2.555)	0.251** (2.294)
Park/school density	0.200** (2.195)	0.237*** (2.754)
Employee density	0.005*** (4.586)	0.004*** (3.783)
Intersection density	-0.799*** (-4.886)	-0.597*** (-3.703)
R^2	0.703	0.744
Adjusted R^2	0.681	0.720
F-statistic	31.951***	30.874***
n	117	117
Note: Numbers in parentheses are t-statistics, */**/*** indicates significance at the 0.10/0.05/0.01 percent confidence levels		

The final result is an estimate that 28.58% of the workers sixteen and over within the City Center II pre-development NMT service area take NMT to work. The percentage will increase to 30.68% post-development. If these estimated percentages are applied to the calculated population totals, the City Center II project will increase the amount of people who take non-motorized transportation to work from 2,115 to 2,291, within its NMT service area.

Table 4 shows the final calculations for all nine variables for the pre- and post-development non-motorized transportation service areas. Refer to table 3 for units of measurement for each variable.

Table 4 Variable Measurements

	Pre-Development	**Post-Development**
Population Density	12.75	12.86
Path, lane, and trail density	80.06	81.35
Sidewalk ratio	1.9001	1.9211
Commercial property density	0.1565	0.1572
Real node ratio	0.9047	0.9274
Park/school density	0.2736	0.2748
Employee density	14.794	17.648
Intersection density	0.3084	0.3111

All of the variables increased in density, although, employee density had the largest increase. Employee density increased from approximately 15 employees per acre to 18 – resulting in a 19.3% gain.

Table 5 explores where the greatest gains will occur post-development, according to the model. The top line of percentages shows the estimated influence that each variable had in the overall amount of people who took NMT to work pre-development. The second line of percentages has the estimated change post-development. Those two lines added up equal the third line, the final estimated percentage of people who will take NMT to work post-development.

Table 5 Changes in Estimates

	Pre-Development NMT Estimates	**Changes in Estimates After Development**	**Total[5]**
Path, Lane, and Trail Density	24.018%	0.387%	24.405%
Connected Node Ratio	22.708%	0.57%	23.278%
Sidewalk Presence	8.740%	0.097%	8.837%
Park/School Density	6.486%	0.027%	6.513%
Employee Density	5.918%	1.142%	7.059%
Population Density	3.825%	0.033%	3.858%
Commercial Property Density	2.394%	0.011%	2.405%
Intersection Density	-18.413%	-0.162%	-18.575%

[5] The TOTAL line adds up to 57.78% because the constant value of (-27.1%) needs to be added.

CHAPTER 5

DISCUSSION

The purpose of this project was to develop a model that estimates the change in NMT after a land use change. The example of a redevelopment in East Lansing was chosen because of the ease of access to the development details. Therefore, this example of the application of the model is reflective of the land use characteristics of the Lansing MSA. This area includes the State of Michigan Capitol, Michigan State University, and other unique land uses.

While the results of this model are particular to the Lansing MSA, the methods can be universally applied. This can result in substantial changes in the way that non-motorized transportation grants are applied for and awarded. In addition, if a method to quantify the outcomes of NMT projects can be created, the disproportioned rate of traditional motorized transportation projects compared to non-motorized transportation may start to decrease.

5.1 Model Results

This model was created using demographics and built environment data from the Lansing tri-county region, which has a large student population. As previously mentioned in the literature review, income has an influence on a person's likelihood of taking NMT to work, and students are predominantly lower-income. Students also live in close proximity to college campuses, where many of them work. Michigan State University, which has enrollment of over 47,000, has an extensive system of sidewalks, walking trails, and bike lanes. Therefore, this model has the regional influence of a high correlation between paths, lanes, and trails and taking NMT to work.

This is not a negative on the model; it has simply adapted to the unique characteristics of the area it was designed for.

Urban designers emphasize the importance of micro-scale features that add up to influence an individual's use and experience of the neighborhood environment (Alfonzo et al., 2008). This project adds to that literature. The eight built environment characteristic changes accumulated to increase the amount of people who took non-motorized transportation to work, but it was through small increases to each variable. Although the total percentage of the amount of people who took NMT to work increased by 2.1%, it was through incremental increases in all variables.

In regard to the City Center II development, according to the City of East Lansing City Center II project website, the "project will make East Lansing more pedestrian and bicycle friendly by bringing residents closer together to where they work, shop and partake in leisure activities." This analysis suggests that the statement is statistically factual. However, it remains uncertain that that the results indicate a functional difference in NMT from a planning, community, or placemaking perspective. The development will not significantly increase the population density, but it will have a positive effect on the employee density. The development will bring more jobs to the area, but the overall increase in NMT use – from 28.6% to 30.7% - is negligible.

5.2 Policy Implications

In 2005, Public Law 109-59 was passed. Section 1807 established a Non-Motorized Transportation Pilot Program in which four communities would receive $6,250,000 per fiscal year, for four years, in order "to demonstrate the extent to which bicycling and walking can carry a significant part of the transportation load, and represent a major portion of the transportation solution, within selected communities." Over the course of four years the four communities - Columbia, MO; Marian County CA; Minneapolis Area, MN; Sheboygan County, WI - were required to “construct... a network of nonmotorized transportation infrastructure facilities, including sidewalks, bicycle lanes, and pedestrian and bicycle trails, that connect directly with transit stations, schools, residences, businesses, recreation areas, and other community activity centers."

The final report for the pilot programs was published in April, 2012 and it went into detail regarding the insights and lessons learned. One of the lessons learned was that it took longer time than the program offered to identify, plan, implement projects, and collect data for program evaluation (Federal Highway Administration, 2012). This process could be streamlined by forecasting demand changes using the NMT model presented in this study, similar to how other transportation models operate. The ability to predict changes in usage prior to the actually construction of infrastructure and changes in land use would be an advantage when apply for federal grants and reporting on their progress.

On August 1, 2010 the State of Michigan was the first state in the union to pass Complete Streets legislation (P.A. 135, of 2010). The City of Lansing was the first municipality in Michigan to pass a Complete Streets Ordinance in 2009 and Lansing Township was the first township to pass the ordinance in 2011. The State of Michigan Law and local ordinances require that transportation designing and planning should consider all road users, including pedestrians and bikers, during all phases of a transportation project. The decisions to include such things as bike lanes and sidewalks will ultimately be sensitive to budget, time, and feasibility, among other factors. This leaves a gap in decision making when prioritizing complete streets projects.

Without the ability to predict the benefits of a complete street, non-motorized transportation cannot be judged or valued relative to other transportation mode projects.

Future improvements to regional non-motorized transportation models will help place bicycles and pedestrians on a “level playing field” with modernized modes in transportation planning (Porter et al., 1999). States spend only 1.6% of their federal expenditures on bicycle and walking, or approximately $2.17 per capita (Alliance for Biking & Walking, 2012). As the amount of non-motorized transportation benefits expands, the ability to spend the small amount of appropriated money wisely becomes a priority.

CHAPTER 6

LIMITATIONS AND FUTURE RESEARCH

6.1 Critique of Model

This model is development specifically for the Lansing-East Lansing MSA. Therefore, the coefficient values may not accurately reflect other regions. Some variables, such as topography and subway access, are omitted because they did not apply to this region. While others, such as retail floor area ratio, sidewalk cover, road speed, and traffic counts, are left out because of a lack of information/data. Despite these data limitations, the final model did account for a large amount of the variance (r-square value of 0.744).

Further research needs to be conducted in order to understand the relationship between the variables found not to be significant and NMT. Out of the eight variables included in the model two were not significant at the 0.10, 0.05, or 0.01 levels – population density and commercial property density. Commercial property density had a significance level of 0.153, so the variable was close to being significant. However, population density had a significance level of 0.467. The research on population density is mixed when it comes to increasing NMT. Some researchers have found that it has a positive effect while others disagree. For example, Newman (1992) found that in Australian cities when walking and cycling to work is graphed against population density the result is an S curve.

Newman postulates that the decrease in walking and biking to work between 40 and 90 persons/ha is because there is more access to public transportation. After 90 persons/ha there appears to be a sharp increase in walking/biking to work. This could be because amenities are close enough to not need public transportation, or the public transportation is getting overused.

This theory was accounted for by including taking public transportation to work in the model, but possibly there is more to the story.

The 2005-2009 ACS data set presents the smallest geographic area (census tracts) that includes data related to non-motorized transportation. However, unlike information that planners typically rely upon in the decennial Census long forms – such as means to work – the ACS uses a moving average rather than point-in time data. While the creation of the ACS will give planners a new set of refreshed data every year, there are a number of problems with using the ACS dataset. For instance, the sampling error associated with the decennial census long form was much lower than that of the ACS (Blodgett, 2009).

The problems with using ACS data occur when the study area goes through changes. However, for the current study area, the population has not comparably grown very much since 2000. According to the census, the Lansing tri-county population grew 3.64% between 2000 and 2010, near one-third of the national average of 9.71%.

In general, The ACS is a good resource for socio-economic data in larger study areas, such as national, states, larger cities, counties, and metro areas; however, the reliability decreases as the study area gets smaller. Therefore, if this model is going to be adapted to a rapidly changing region, more accurate survey data is needed.

There is a difference between walking for transport and walking for recreation. This project aimed to estimate the change in resident's behavior towards taking NMT as a means for transportation to work. Although, some researchers have found that the built environment characteristics that influence transport to work also influence recreational travel (Cerin et al., 2006; Alfonzo et al., 2008). In contrast, other researchers have found no relationship between the built environment and recreational walking (Learnihan et al., 2011). Still other researchers found that different built environment attributes were associated with recreational walking versus transportation walking (Lee &Moudon, 2006). The only survey data available related to NMT in the Lansing region was American Community Survey means to work. So, these differences were not able to be explored.

Other researchers have found that people are willing to walk further if the area is highly walkable (Park, 2008). Therefore, because there was a relatively large amount of people taking NMT to work pre-development (28.58%) – implying a highly walkable area – the effects of increasing the walkability of the area may have been felt further out then the half-mile service area created for this project. This concern could be solved by utilizing better survey data, which was not at the disposal of this researcher.

Finally, in the process of creating this model other questions have risen. For example, do the same variables influence the likelihood that people will take NMT from different socio-economic classes? For example, is the access to close employment the most significant variables when it comes to predicting if high-income individuals take NMT to work? Conversely, is access to sidewalks, paths, trails, and bike lanes the best predictor for low- to medium-income individuals?

6.2 Future Use for the Model

This model was applied to a relatively small proposed redevelop in a dense, mixed-use downtown area. However, the methods used could also be applied to larger land use changes. Expand and give other thematic potential applications, nothing too specific in this section. We are trying to make your last points on your soap box, not open up lots of questions.

In addition to quantifying the effects of proposed land use changes, this model would be a valuable tool for master plans, neighborhood plans, non-motorized transportation plans, and any other plans that are created to guide the land use decisions of a community. Many community plans involve aesthetically pleasing long-term goals/strategies for underutilized areas. For example, the City of East Lansing published an East Village Master Plan in 2006. This 36 acre mixed-use redevelopment project will replace the current student housing in the area. However, this project has yet to get off the ground. The Master Plan published has lots of beautiful renderings of the proposed redevelopment, but there are no quantified benefits within the Plan. The ability to show how much an area will benefit from reinvestment may go a long way in gaining momentum for the project.

Transportation models can help foster economic development by assessing the need, quantity, and benefit of infrastructure improvements. The economic benefits of non-motorized transportation have already been discussed, and if communities are subscribing to the theory of placemaking, then the ability to quantify changes will be a great tool to possess. This paper went into the benefits, methods, and possible uses of such a model. The need for better research data has been exhausted in this paper and in countless others, but that is the last step in making this model possible and realizing the benefits.

This project used the only non-motorized transportation survey data available for the Lansing area. However, the question this project asked and the method itself were unique and they add to the growing amount of research related to improving non-motorized transportation in America. Once a model is created distinctive to that community, calculating how a new development changes the ability for the residents to take NMT will be easy. These simple methods can have a place within a community's site plan review, or at least as a marketing tool to attract future residents of a development.

APPENDICES

APPENDIX A

Table 6 Correlations

	Means to Work	Population Density	PLT Density	Bus Stop Density	Sidewalk Presence	Commercial Property Density	Connected Node Ratio
Means to Work	1	.569**	.569**	.592**	.597**	.313**	.333**
Population Density	.569**	1	.531**	.711**	.720**	.365**	.349**
PLT Density	.569**	.531**	1	.417**	.440**	.081	.077
Bus Stop Density	.592**	.711**	.417**	1	.745**	.531**	.458**
Sidewalk Presence	.597**	.720**	.440**	.745**	1	.276**	.455**
Comm. Property	.313**	.365**	0.81	.531**	.276**	1	.175
Connected Node Ratio	.333**	.349**	.077	.458**	.455**	.175	1
Park / School Density	.550**	.434**	.481**	.357**	.491**	-.016	.174
Residential Density	.324**	.858**	.318**	.721**	.672**	.510**	.384**
Effective Walking Area	.110	.656**	.249**	.591**	.564**	.353**	.401**
Employee Density	.608**	.329**	.287**	.613**	.424**	.583**	.263**
Intersection Density	.224**	.667**	.259**	.661**	.629**	.443**	.447**

** Correlation is significant at the 0.01 level (2-tailed)

***** Correlation is significant at the 0.05 level (2-tailed)

Table 6 (cont'd)

	Park / School Density	Residential Density	Effective Walking Area	Employee Density	Intersection Density
Means to Work	.550**	.324**	.110	.608**	.224*
Population Density	.434**	.858**	.656**	.329**	.667**
PLT Density	.481**	.318**	.249**	.287**	.259**
Bus Stop Density	.357**	.721**	.591**	.613**	.661**
Sidewalk Presence	.491**	.672**	.564**	.424**	.629**
Comm. Property	-.016	.510**	.353**	.583**	.443**
Connected Node Ratio	.174	.384**	.401**	.263**	.447**
Park / School Density	1	.138	.071	.263**	.186*
Residential Density	.138	1	.812**	.223*	.780**
Effective Walking Area	.071	.812**	1	.141	.894**
Employee Density	.263**	.223*	.141	1	.307**
Intersection Density	.186*	.780**	.894**	.307**	1

** Correlation is significant at the 0.01 level (2-tailed)
***** Correlation is significant at the 0.05 level (2-tailed)

APPENDIX B

Table 7 Model without SES Controls

Regression Statistics	
Multiple R	0.838
R Square	0.703
Adjusted R Square	0.681
Standard Error	0.08848
Observations	117

ANOVA

	df	SS	MS	F	Significance F
Regression	8	2.001	0.250	31.951	.000
Residual	108	0.846	0.008		
Total	116	2.947			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.237	0.092	-2.568	0.012
Pop_Density	0.009	0.004	2.277	0.025
PLT Density	0.003	0.001	3.759	0.000
Sidewalk Presence	0.056	0.020	2.734	0.007
Commercial_Density	0.179	0.113	1.588	0.115
Connected Node Ratio	0.297	0.116	2.555	0.024
Parks & Schools Density	0.200	0.091	2.195	0.030
Intersection Density	-0.799	0.164	-4.886	0.000
Employee Density	0.005	0.001	4.586	0.000

APPENDIX C

Table 8 Full Model

Regression Statistics	
Multiple R	0.8628
R Square	0.74442
Adjusted R Square	0.72031
Standard Error	0.08285
Observations	117

ANOVA

	df	SS	MS	F	Significance F
Regression	10	2.1192561	0.21193	30.8741756	4.94287E-27
Residual	106	0.7276021	0.00686		
Total	116	2.8468582			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.271	0.135	-2.003	0.048
Pop_Density	0.003	0.004	0.730	0.467
PLT Density	0.003	0.001	4.669	0.000
Sidewalk Presence	0.046	0.019	2.341	0.021
Commercial_Density	0.153	0.106	1.444	0.152
Connected Node Ratio	0.251	0.110	2.294	0.024
Parks & Schools Density	0.237	0.086	2.754	0.007
Intersection Density	-0.597	0.161	-3.703	0.000
Employee Density	0.004	0.001	3.783	0.000
Income	0.000	0.000	-3.659	0.000
Gender	0.367	0.211	1.742	0.084

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