USE OF GIS MODELING FOR CREATING ALTERNATE FUTURE SCENARIO FOCUSING ON INTEGRATING URBAN AND TRANSPORTATION DECISIONS FOR POLK AND HIGHLANDS COUNTY, FLORIDA

By

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To Aarav Naik, my beloved son who is my motivation, and Jayant Naik, my wonderful husband who is my strength for this master's degree

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LIST OF ABBREVIATIONS

ACS	American Community Survey
AG	Agriculture
ASCS	Areas of Critical State Concern
BRT	Bus Rapid Transit
CO2	Carbon Dioxide
CAA	Clean Air Acts of 1970 and 1977
CAAA	Clean Air Act Amendments of 1990
CAFÉ	Corporate Average Fuel Standards
COM	Commercial
CBD	Central Business District
CFRPC	Central Florida Regional Planning Council
CSS	Context Sensitive Solutions
DLU	Developable Land Units
DOT	United States Department of Transportation
DRI	Development of Regional Impact(s)
EIS	Environmental Impact Statement
FDOR	Florida Department of Revenue
FDOT	Florida Department of Transportation
FGDL	Florida Geographic Data Library
FHWA	Federal Highway Administrations
FLUAM	Future Land Use Allocation Model
HFC	Hydro-fluorocarbons
GHG	Greenhouse Gas

GIS	Geographic Information System(s)
GUI	Graphical User Interface(s)
IND	Industrial
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
IPCC	Intergovernmental Panel on Climate Change,
LRT	Light Rail Transit
LRTP	Long-range Transportation Plan
LSMPO	Lake-Sumter Metropolitan Planning Organization
LUCIS	Land Use Conflict Identification Strategy
MF	Multi-Family
MPO	Metropolitan Planning Organization
MTPO	Metropolitan Transportation Planning Organization
MVP	Mobility Vision Plan
MXD	Mixed use Development
NEPA	National Environmental Policy Act of 1969
NHTS	National Household Travel Survey
PUD	Planned Unit Development(s)
RET	Retail
RACEC	Rural Area of Critical Economic Concern
SER	Service
SF	Single- Family
SACOG	Sacramento Council of Governments
SOV	Single-occupant vehicle(s)

SUA	Single Utility Assignments
TAZ	Traffic Analysis Zone(s)
TEA21	Transportation Equity Act for the 21st Century
TOD	Transit-Oriented Development
TDM	Transportation Demand Model
TDP	Transit Development Plan
TPO	Transportation Planning Organization
UF	University of Florida
VMT	Vehicle Miles of Traveled

Abstract of Thesis Presented to the Graduate School
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Chair: Ruth L.Steiner
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Understanding the impact of proposed development projects and anticipating the future is a challenging tasks for the metropolitan regions and metropolitan planning organizations (MPOs), who are attempting to incorporate the federal requirements of linking land use and transportation, and are also trying to address vital issues, like increases in green house gas emissions (GHGs) with increasing sprawl, traffic congestion, decreasing housing affordability, and loss of open spaces. MPOs have been using the traditional planning models for predicting the future, and are not equipped to address these issues successfully, as they do not easily integrate land use and transport decisions. Therefore, these models need to be more sensitive to the future needs recognizing this feedback between transportation and land use and providing avenues for more sustainable development patterns

This research is based on the concept that thoughtful allocation and sensible use of land in conjunction with proposed transport projects, like public transit (bus or commuter rail), coupled with land use suitability analysis techniques can improve the achievement of mutually supportive land use and transportation goals, integrating them

for a more sustainable development. The study utilizes the vision developed by the long range transportation plans for the 2035 scenario for the Polk and Highlands County as guidelines to propose alternate land use scenarios for period of 2006-2035 that promote a compact development pattern with reduced urban sprawl and vehicle miles of traveled (VMT), conserve natural areas and promote economic stability. The study creates alternate scenarios using Land Use Conflict Identification Strategy (LUCIS) method (Zwick and Carr, 2007) and uses the transportation models prepared by the respective counties for 2035 with subsequent assumptions for comparison with one proposed in long range plans.

The results after the modeling the alternate scenario based on set of pre assumed conditions shows a more compact development, promoting conservation in energy, reduction in VMT than the existing development pattern. The modeled scenario for Polk County allocates an average of 62% of total population within the 3-mile buffer distance from transit routes and station at higher densities as compared to long-range transportation plans. Similarly, in case of Highlands County, the LUCIS based scenario allocates about 80% of the total growth inside the 3-mile distance from the transit route and stop. The scenarios also conserve natural areas and ecosystem, with prime agricultural land. The study highlights that the method based on land suitability aimed to integrate land use and transport decisions can provide a more comprehensive tool to planners and planning organizations. This tool is more effective in predicting land allocation locations for future growth that meet specific planning guidelines designed to enhance the coordination of long-range land use and transportation decision, without comprising the sustainability of the development.

CHAPTER 1
INTRODUCTION TO THE TOPIC

Decision Making Tools and New Planning Approach in a Metropolitan Planning Organization (MPO) Region

Transportation accounts for about 30% of total greenhouse gas emissions and is the fastest growing end-use sector of U.S. greenhouse gas (GHG) emissions. Carbon dioxide (CO2) is the most commonly emitted greenhouse gas, accounting for 95 % of U.S. transportation emissions in 2006. As transportation both contributes to, and is affected by climate change, research in recent years has focused both on mitigation of transportation's contributions to greenhouse gas emissions and adaptation to potential impacts on infrastructure. It is widely known that land use changes impact transport decisions and vice a versa. Hence, requiring additional research to better understand and evaluate how various strategies, such as land use changes, policy initiatives and infrastructure construction and management approaches, may affect and address the issues of the transportation sectors like increase in VMT leading to emissions of GHGs in a metropolitan area.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 has redefined the role of MPOs in the transportation decision-making process. In addition to providing MPOs with greater authority in defining regional transportation systems, the Act emphasizes intermodal planning, greater community, and private sector involvement in developing plans and programs. Recognizing the effects of transportation on land use and the environment, ISTEA and the Clean Air Act Amendments of 1990, mandated that MPOs integrate metropolitan land use and transportation planning. The passage of the Transportation Equity Act for the 21st Century (TEA21) in 1998, as the successor to ISTEA, softened these planning requirements somewhat, but significant pressure remains to coordinate metropolitan planning of land use, transportation, and the environment. (Waddell, 2002, pg.2) Federal transportation planning regulations and policies included in the current SAFETEA-LU legislation also encourages visualization and scenario planning as a method to support integrated land use and transportation planning and to strengthen public participation in the planning and project delivery process.

Scenario planning is a technique that allows organizations to prepare for potential future conditions. Instead of planning for a single predicted future, strategic planners began developing ranges of possibilities for the future that allowed them to identify common strategies to pursue in preparation for all of the possibilities. (Federal Highway Administration, 2011, pg.11)

The Federal Highway Administrations (FHWA) research suggests scenario planning as one of the best possible strategy for considering the integration of climate change in to transportation planning process, as it helps the local government in:

- Promoting different development types (e.g., transit-oriented development or TOD) that are conducive to GHG emission reductions and improved air quality.
- Helping the public and elected officials visualize and understand the impacts of future growth according to climate change-related criteria such as VMT, gallons of gas consumed, or GHG emissions.
- Allowing better decision-making on ways to address vulnerabilities, such as transportation infrastructure located in low-lying coastal areas.(FHWA Scenario Planning and Visualization in Transportation, n.d)

Throughout the United States, metropolitan regions face increasingly complex issues related to transportation and land use. The diffuse nature of decision-making creates a need to coordinate land use and transportation to address known issues of congestion, infrastructure costs, economic vitality and greenhouse gas emissions. Key players in this decision-making are regional MPOs with transportation planning authority, regional planning responsibilities, and in some cases regional land use planning authority. (Margerum,R., Brody,S., Parker, R., McEwen, G., 2011,pg. 9)

Linking the Land use and Transport Decisions for Long Range Planning

Metropolitan areas have a challenging task to incorporate the federal requirements of linking land use, transportation, and growing concerns of the degradation in environment with increasing sprawl, traffic congestion, decreasing housing affordability, and loss of open spaces. The earlier planning models used by MPOs were generally not designed to address these questions, resulting in decreased ability of planners to predict the changes and its future impacts. (Waddell, 2002, pg.1)

Over the past decade, there has been growing interest in integrating transportation and land use planning, based on a recognition that land use not only influences transportation outcomes, but that transportation investments also influence land use decisions, potentially undermining the benefits of capacity expansion aimed at relieving urban congestion problems. This recognition of feedback between transportation and land use has led to calls for integrating land use and transportation models used in the metropolitan planning process. (Waddell, 2001, pg.1)

Todd Litman in his research report identifies the impact of land use and transportation on each other and points out the lacunas in the modeling system as

> Current transportation models are not accurate at predicting their effects. For example, most models use analysis zones that are too large to capture small-scale design features, and none are very accurate in evaluating non-motorized travel. As a result, the models are unable to predict the full travel impacts of land use management strategies such as TOD or walking and cycling improvements. (Litman, 2011, pg.45)

The models and tools used in the preparation of long range transportation plans for a MPO region are the reflections of the predictions of the future. Therefore, they need to be sensitive to the impending needs and impacts of future transportation policies on land use to reflect the effects of transportation policies like, impact of GHG emissions and VMT.

Research Question and Study Objective

House Bill 697, signed by the Governor Charlie Christ on June 17, 2008, and the Energy Bill, HB 7135, amends the local and state comprehensive plan to include goals related to energy and global climate change (Energy Initiatives., DCA, n.d). The Bill also provides that each MPO is encouraged to consider strategies that integrate transportation and land use planning to provide for sustainable development and reduce greenhouse gas emissions (Overview of local planning, n.d). The preparation of long range transportation plan (LRTP) by a MPO is based on the results of the various models for predicting the future land use and transportation requirements of the region. These models describe the probability of impact of land use changes on transportation; and vice versa, however in order to promote the reduction in VMT and greenhouse gas GHG reduction these models should reflect their impact too.

The idea of the current research is based on the concept that

> Transport planning decisions affect land use development, and land use conditions affect transport activity. (Litman, 2011)

Since there is a strong interaction between land use and transportation, they need to be coordinated with each other in preparation of long range plans to avoid the increasing GHG emissions with VMT.

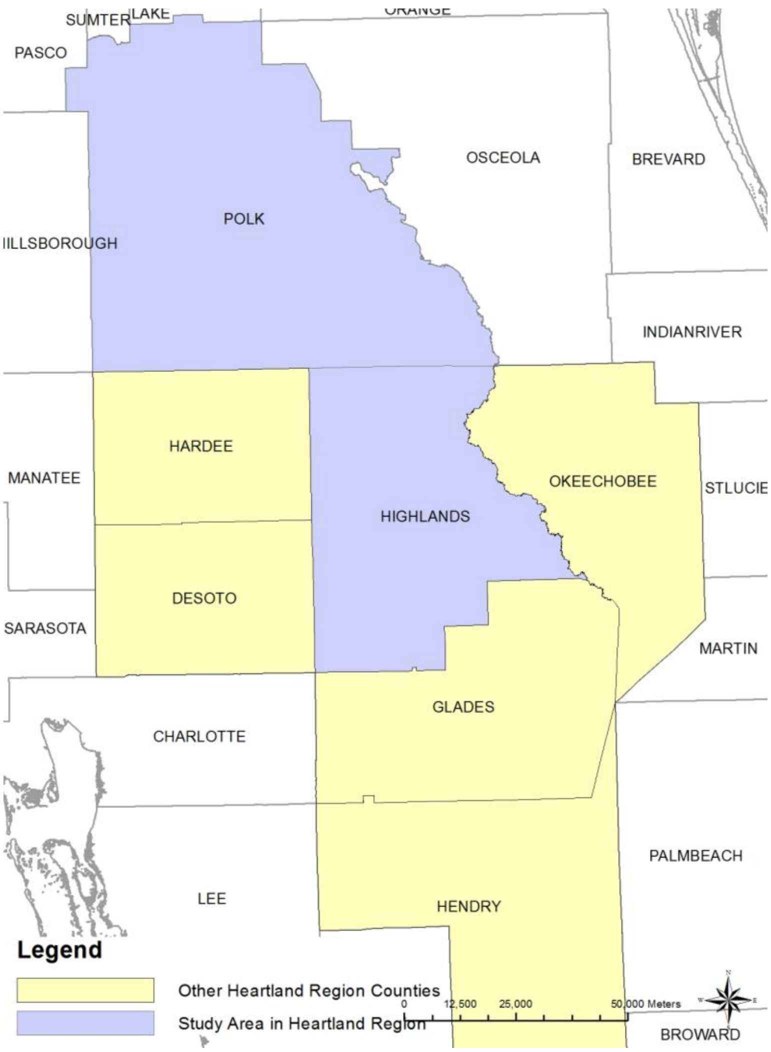


Figure 1-1. Shows the counties in Heartland Region Florida, Map Courtesy of Author

Current research interest in the field of integrating the land use and transportation decisions for forecasting the change is using smart growth to reduce the impact of growing GHG emissions and VMT has formed a base for this research. This study extends that research by studying the existing scenario of the selected case study and its projected scenario for future and then analyzing the proposed scenario with an alternate scenario created using the land suitability analysis method. The study aims to utilize the LUCIS method, which allocates population to the land based on its highest suitability. The study aims to utilize the LUCIS method, which allocates population to the land based on its highest suitability. The study intends to use the transportation projections from the long rage plan for individual counties to compare the results and analyze the effectiveness of the method. The objective of the research is to identify a method that is more predictable and sensitive to future needs of the counties and integrates future land use and transport decisions effectively. This research also analyses the effectiveness of population distribution prediction by LRTP of each county in providing a compact, sustainable development for future, by comparing the results of the long range plan scenario for each county with LUCIS based scenarios using indicators,

Heartland region comprises of the seven counties in the rapidly growing central region of Florida, including Polk, Hardee, Highlands, Desoto, Okeechobee, Glades and Henry. The Polk and Highlands County of the region have developed their long-range transportation plan based on the traditional method and utilizes socio economic data for 2035 vision. The whole Heartland region is developing its vision for 2060 and utilizes the socio economic forecasts predicted for the 2035 scenario for the region.

Problem Statement

MPOs will play important roles in addressing the issue of GHG and VMT reductions in the transportation sector. Florida law now encourages MPOs to consider strategies to integrate land use and transportation planning to reduce greenhouse gas emissions, as part of its Long-Range Transportation Plan process.

The 2035 Mobility Vision Plan (MVP) for Polk County and Long-Range Plan for Highlands County take into account growth over the next 25 years as envisioned in locally adopted Land Use and Comprehensive Plans, with large and statewide transportation development needs and decisions. Since the counties are the two largest in area and have a possible spillover effect of development into other Heartland Counties in the future. Therefore, this research will be based on the careful analytical assessment of the land use model prepared by the Polk County and Highlands County by comparing it with an alternate land use scenario that will be created using the goals and visions of the adopted plan.

The aim of the study is to provide the planning professionals and responsible government agencies a comparative analysis of the results of two forecasting methods used for long-range plans. One method uses the land suitability analysis (LUCIS) and another being the traditional method used by counties. The study aims to analyze the strengths and limitations of the methods by comparing the results for a more comprehensive understanding, and to identify the important parameters in coordinating the land use and transport decisions to satisfy the goals of long-range planning with the help of performance indicators.

The two methods of comparison of results for both land use and transportation future scenarios are different on following levels. The method adopted by Polk County for the development of the future scenario uses historical development trends, comprehensive plan policies and a mathematically derived gravity model to allocate future population and employment growth. In case of Highlands County, the future scenario was evolved using the transport demand and land use model prepared by the county based on trends and developable land analysis, (the details of the land use model used by the county, was not available). On the other hand, the research study uses the land use suitability analysis and scenario (LUCIS) developed by Dr. Paul Zwick and Margaret Carr from University of Florida. The LUCIS methodology uses on planning techniques that allocates future growth according considerations of land use suitability. The research aims to prove that thoughtful allocation and sensible use of land in conjunction with proposed transport projects based on land use suitability analysis and scenario-planning techniques can improve the achievement of mutually supportive land use and transportation goals, integrating them for a more sustainable development.

Objectives of the Research

The intended research aims to analyze the issues with following objectives as guide and step-by step guidance for the study of the intended research:

1. To understand the interdependence of transportation and land use and the importance of the relationship for reduction in VMT and GHG emissions

2. To study and evaluate the effectiveness of state and local policies in the long range transportation plan for a region to determine if they incorporate effective policies that encourages compact development as a means to reduce GHG emissions along with VMT from the transportation sector.

3. To create alternate land use scenario model for the selected counties of Polk and Highlands in Heartland region using the LUCIS and compare it with existing growth scenario for the respective county used in the preparation of long-range transportation plan.

4. To analyze the effectiveness of both models used in predicting the land use and transport scenarios for 2035 for achieving the goals of smart growth, GHG and VMT reduction for the region with the help of suitable performance indicators.

CHAPTER 2
LITERATURE REVIEW

Introduction

Transport and land use are dependent on each other, influencing each other in many ways. Cervero (2009) identifies transport network in the form of road and streets as a necessity for the accessibility benefits in shaping our built environment. Land use, urban environment and development pattern can generate the demand for transportation and reduce the need for motorized trip making. This interdependency, of land use and transport makes it and necessary to integrate and weave them together for a socially, environmentally and economically sustainable future. (Cervero, 2009, pg.1) The land use/transportation integration is often viewed as an important method to reduce traffic congestion and develop compact development patterns.

The efficiency of travel patterns is mainly associated with land-use characteristics like dense residential or employment development, mix of complementary land uses within small areas. These land use characteristics are in turn associated with transportation infrastructure and facilities that support efficient travel behavior, such as frequent transit service, and complete sidewalk and bike lane networks on arterials, collectors, and local streets (Moudon, A, Cail, M., Pergakes,N., Forsyth, C., Liilard, L., 2003, pg.18)

Integration of transport decisions with land use also helps to create livable communities, which refer to environmental and social quality of an area as perceived by residents, employees, customers and visitors. Livability also refers to safety and health (traffic safety, personal security, and public health), local environmental conditions (cleanliness, noise, dust, air quality, and water quality), the quality of social interactions (neighborliness, fairness, respect, community identity and pride), opportunities for recreation and entertainment, aesthetics, and existence of unique cultural and environmental resources (e.g., historic structures, mature trees, traditional architectural styles). (Litman, 2011, pg.1)

Governmental agencies at various levels are increasing aware and under increased pressure to reconsider, their land use and transportation policies in order to reduce the VMT as a result of automobile oriented development patterns, and resulting GHGs, and lessen the potential impact of climate change. Based on current GHG emission reporting guidelines, the transportation sector directly accounted for about 28 % of total U.S. GHG emissions in 2006, making it the second largest source of GHG emissions, behind only electricity generation (34%). (US Dept of Transportation, 2012) Nearly 97% of transportation GHG emissions came through direct combustion of fossil fuels, with the remainder due to carbon dioxide (CO2) from electricity (for rail) and Hydro fluorocarbons (HFCs) emitted from vehicle air conditioners and refrigerated transport. Transportation is the largest end-use sector emitting CO2, the most prevalent greenhouse gas. (US Dept of Transportation, 2012)

The Florida’s Climate Change and Action Plan (2008) identify the transportation sector as the second largest contributor to Florida’s gross green house gas (GHG) emissions. The transport sector accounts for about 41% of the state’s net growth in gross GHG emissions, and recommends use of smart growth, improvement in transportation system management and land use planning process by increasing multi-modal activities in long range planning.

This interaction of land use and transportation on each other and importance of changing transport policies for future development pattern will play an important role in assessing their role on reduction of VMT and GHG reduction targets. However, in order to establish the suitable strategies to overcome the impact of increased VMT leading to increase in GHG emissions, understanding the relation between urban form and travel behavior with their connection with VMT and GHG is crucial.

This review of the literature seeks to evaluate the role of coordination between land use and transportation decisions, with respect to policy and modeling perspective relating to the concerns of growing VMT and GHGs environmental impacts. Firstly, the Chapter 2 evaluates the relationship between built form, VMT and GHG emission to understand the factors for decreasing impact of VMT and GHGs from transportation sector and existing development pattern, as changing development pattern is a very complex process for any future decisions. However, by understanding the relationship between various aspects of urban form and transportation options, the modeling choices and options that can support the goal of VMT and GHG reduction are easier to identify and analyze. Both the roles of policy and individual land use and transportation decisions addresses in their impacts to regional land use patterns and the necessity to understand the power of each to contribute to or detract from regional goals.

Secondly, the process of predicting the future development pattern plays an important role in successfully analyzing the impacts of land use and transportation on each other. Hence, it will be imperative to understand the process of integrating land use and transportation and their importance of their coordination in tackling the issues of decision-making on climate change, increased VMT. Therefore, the second part of literature review assesses the methods, including various GIS-based applications, for the coordination and integration issues of land use and transportation and the associated climate change impacts. One of the focused aspects of the literature review is the use of scenario planning methods for predicting future land use as a tool, for assessing the impact of growing GHGs and VMT in the various regions.

Relationship between Urban Form, VMT and GHG Emissions

If people drive fewer miles, they will use less fuel and emit fewer GHGs. Reducing VMT by means of ‘‘smart growth” policies have rapidly become the central focus of reducing transportation GHG emissions. The argument is that denser, compact, mixed-use development will change the travel behavior of individuals and households, and those changes will lead to fewer GHG emissions. (Ewing et al., 2008; TRB, 2009)

Famous Five Ds

Numerous research studies completed in the last two decades focuses on the relationship between built environment and travel impacts. Although different studies with different approaches have been undertaken to understand the land use characteristics, a consensus exists that role of five Ds i.e. Density, Diversity, Design, Destination accessibility, Distance to Transit plays an important role in judging the travel behavior. The concept of three Ds – density, design, diversity were originally investigated by Cervero and Kockelman (1997) in their research study based in San Francisco bay area, where they modeled the impact of density, diversity and design on VMT. The notion of both density and design is not new to the development patterns. Density was first used in the Garden City movement in England; it is most commonly defined as ratio of population or dwelling units to area like hectare (Pont and Haupt, 2007), where as design is a process of transforming ideas in to the reality with use of imaginations and measurement units like density to create built forms and development patterns. Design relates to interconnectivity of streets, housing patterns and use of open spaces. Diversity, the third leg of the 3Ds is the various mixes of land uses or housing types in the development pattern.

The remaining Ds like the destination and distance to transit added up to the scenario with time. The Transportation Research Board Report (2009; p. 32) defines destination accessibility as

> The ease or convenience of trip destination from point of origin, often measured at the zonal level in terms of distance from the central business district or other major centers

And distance to transit as

> Ease of access to transit from home or work (e.g., bus or rail stop within quarter to half-mile of trip origin).

Recent literature has shown destination accessibility as an important variable when looking at household VMT (Ewing and Cervero, 2001).The National Research Council report (2009) also identifies destination accessibility and distance between development and transit as another two factors, along with the most common identified and referred as five Ds – density, diversity, design, destination accessibility and distance to transit. Bailey, Mokhtarian & Little (2008) summarize the existing literature on built environment and transportation focusing on mainly land use - urban environment as one of main characteristics with socio-demographic factors, and cost of travel. However, in another recent study by Chen, Gong and Paaswell (2008), the authors assess the importance of density relative to other built environment variables like job accessibility with respect to the central business district (CBD) and distance to transit stops from work and home. Their study in general establish the role density plays in mode choice decisions in home-based work tours while controlling for confounding factors. The research used a travel data collected from households in New York Metropolitan region (1997 -1998) based on travel patterns and socio-economic characteristics and focus on trip chain, instead of single trip, which was a unique feature of the research, as it reflects the true pattern of commuter travel. The authors conclude that, although self-selection is a key factor in interpreting the importance of built environment, job accessibility with respect to transit also exerts a significant contribution. (Chen, Gong & Passwell, 2008)

In an attempt to understand the relationship between built environment and travel demand, Cervero (2003), investigates various past studies done on different aspects of land use characteristics, like density, mixed use, to determine the various factors for considering in travel demand modeling. Cervero identifies density as playing as an important role in shaping the travel pattern and as a collective tool for reducing the VMT. He stresses the use of disaggregated studies for assessing impact of travel pattern on land use based on individual and household level. Cervero (2003) also emphasizes on careful consideration for site for comparing the neighborhood design and built environments. The author claims that most of the U.S. studies of travel and different dimensions of the built environments have concentrated on residential neighborhoods far more than on non-residential settings like suburban activity centers (e.g., office parks; edge cities). For the most part, the elasticity's between land-use characteristics and travel for workers tend to be equally weak for nonresidential settings. He insists that the travel demand management can exert strong impacts on the travel behavior leading to reduction in VMT, hence use of integrated land use and transportation policies are required for a sustainable community design. He in his research stresses on the importance of design i.e. road network among the 5 Ds as one of the impacting factors for understanding the relation between urban form, VMT and GHG emissions.

Many researchers have shown that the changes in density of population or employment directly affect the VMT, which is a combination of factors; trip distance, trip frequency, and share of motorized travel. The impact of any land use strategy on these factors individually can be different and can lead to reduction in VMT (Zhang, 2010). Researchers like Cervero (2003) and Litman (2011) agree that use of a land use strategy for mixed use or compact development like TOD, implementing urban design concepts, can also affect the travel pattern on land use and VMT. For example, location of residential and work place in a transit friendly or walk able environment can help reduce the use of private vehicles leading to reduction in use of single occupant vehicles (SOV) and total VMT.

One of the most widely cited study regarding the land use strategies for reduction of carbon footprints is “Growing Cooler: The Evidence on Urban Development and Climate Change”, published in September 2007. Published by Urban Land Institute, the study provides a comprehensive review of various studies and concludes that urban development is both a key contributor to climate change and an essential factor in combating it. The study focuses on the concept of 5Ds for compact development stressing the need for creating the walkable community with TOD. The study explores the best practices in compact development by examining the relationship between land use patterns, travel, and CO2 emissions. According to the co-author of the study, Prof.

Bartholomew, who analyzed about 23 studies for the report, compact scenarios generate up to one-third fewer miles driven than business-as-usual scenarios (Bartholomew & Ewing, 2009). The report suggests land use options and strategies like mix of land uses, pedestrian friendly environment and transit options can reduce driving in general to 20-40% of present. According to the report, the winning future scenarios are those with higher degrees of land use mixing, infill development, and population density, as well as a larger amount of expected growth. Further, the report calculates reduction in VMT under a logical set of assumptions and found it as much as 18% by 2050. The authors also calculate the savings in CO2, by assuming that, if 60% of new growth is changed towards the compact development patterns, it saves about 79 million tons of CO2 annually by 2030, and questions the present corporate average fuel standards (CAFÉ) standards. (Ewing,R., Bartholomew,K., Winkelman,S., Walters,J., Chen,D., 2008)

VMT and GHG Connection

In a research study for assessing the connection between public transit, energy conservation and reduction in GHG emissions, Bailey, et al. (2008), tested and studied a similar hypothesis by conducting a research aimed to estimate the effect of public transportation availability on household travel through the medium of land use, specifically on total VMT. The use of structural equations model with National Household Travel Survey (NHTS) data in the research paper revealed that the availability of public transit reduces VMT two times more than the actual transit trips, as it helps in shaping the land use pattern. Bailey, et al. (2008), in their study also claims that the VMT reduction obtained through the statistical model can predict a saving of 3.4 billion gallons of fuel consumption across the entire US with use of public transit. The study also calculated the net CO_2 savings as 37 million metric tones annually, by usage of public transportation, which is result of simply deducting amount of CO_2 burned through each gallon of petroleum with usage of public transportation to motor vehicles. (Bailey, et al., 2008, pg. 6)

However, not all researchers agree that reduction in VMT can automatically reduce the GHGs from the environment through compact land use development. Zhang (2010) in his research paper attempted to discover empirical evidence of a strong relationship between urban form, VMT and GHG emissions. The study was based on the hypothesis that the existing land use tools like mixed use development (MXD) can reduce the VMT, but may not necessarily decrease the GHG emissions. To test the hypothesis in the research, various MXD communities were identified and selected in Austin for comparison and vehicle trips and amount of GHG emissions were calculated for in and out of these MXD communities to the rest of the city. The study concludes that the average daily miles traveled by persons living in MXD is less than that of those in suburban communities; but the amount of GHG emissions by MXD community residents is more than non MXD residents. This seemingly contradictory result is explained by the fact that the residents of MXD communities use more frequent trips at slower speeds, compared to the residents of the non- MXD communities, which uses limited trips but at much higher speeds.

Based on the existing literature surveyed, for relation between built form and VMT and for assessing the land development patterns and policies for GHG reduction, all seem to be concluding a reasonable consensus that

> Land use policies, combined with aggressive investments in transit funded by market-correcting pricing signals can achieve a 10-30% reduction in

> VMT in a 20-30 year time horizon, with the variation explained by assumptions made about the political feasibility and public acceptance of these concepts (Eaken & Goldstein, 2008, p.5)

The various strategies for compact development with use of density and diversity i.e. mixed use development neighborhoods can generate lower VMT leading to reduced GHG emissions, however, other factors like destination, distance to transit, with use of public transit, varying speed limits can alter the results for land use strategy like mixed use development on VMT and GHG reduction. Therefore, in order to evaluate the effectiveness of strategies in implementing integration of land use and transportation focusing on the reduction in VMT and GHG, the process of predicting the future is very important. There are various methods of predicting future, selecting the right method will be the key in selecting the right development option or strategies for future development pattern.

Predicting the Future – Linking Land Use and Transportation Planning

Increasing traffic congestion within and between communities is an impelling force for the people to spend more and more time in traffic and driving greater distances to jobs, housing, and basic services. Transportation investments play a powerful role in shaping the location and character of development in a community and in determining a community's livability and economic vitality. The way communities plan for development in terms of its land uses and infrastructure needs reflects a strong pressure on transportation and travel mode choices. The existing development pattern with its dependence on automobile has affected the environment (e.g. GHG emissions), and quality of life i.e. access to basic facilities like jobs, housing, and services. This is a compelling reason for transportation and land use planners to coordinate and incorporate land use and mode-accessibility considerations for planning transportation investments and to overcome the issues related with transportation and land use integration.

A better way to link land use to transportation for agencies and planners is to evaluate the impacts of transportation investment on the broader community context including the built, natural, and social environments. Several methods of integrating the land use and transportation considerations for a unified decision making exist, however only few of them have been effective in managing the balance and predicting the impact of land use and transportation on each other.

Land Use – Transportation Integration

The Federal Highway Administration (FHWA) identifies the role of transportation professionals as demanding, requiring them to understand how transportation investments can be consistent with the principles and practices of land use planning and development. Improved coordination between land use and transportation can reduce the need for transportation system expansion, saving the cost of expansion expenditures and maintain the quality of life at community level. This coordination is possible by evaluating the effect of land use decisions on transportation system and increasing viable options for people to access opportunities, goods, services, and other resources to improve the quality of their lives. In turn, the transportation planners should be aware of the effects the existing and future transportation systems on land use development demand, choices, and pattern. Integrating land use and transportation planning and development is one facet of "smart growth," defined as –

> Smart Growth is a better way to build and maintain our towns and cities. Smart growth means building urban, suburban and rural communities with housing and transportation choices near jobs, shops and schools. Smart growth approach supports local economies and protects the environment, sustainable development, (What is Smart Growth, para.1)

The integration not only preserves the natural and cultural resources but also helps in sustainable development of communities and neighborhoods. Smart growth is a set of creative strategies to develop in ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land. Communities can create vibrant places to live, work, and play through smart growth approaches that enhance neighborhoods and involve local residents in development decisions by linking land use and transport together The high quality of life in these communities makes them economically competitive, creates business opportunities, and improves the local tax base (Smart Growth, EPA, n.d).

Strategies and Approaches to Integrate Land Use and Transportation

The literature suggests numerous ways to integrate the land use and transportation decisions at the grass root level. The Strafford Regional Planning Council recommends several cost-effective Smart growth strategies to improve communities: Nodal Development/Zoning, Livable Walkable Communities, and Access Management. The Nodal Development/Zoning refers to a concentrated development (e.g. in the form of village) to encourage walking or bicycle use so that land between nodes can be used for low density, low traffic land uses. On the other hand, creating Livable Walkable Communities are provision on municipalities that provide facilities to promote walking, bicycling, services, and activities that promote a healthier lifestyle. The Stafford Regional Council also recommends technique of Access Management, which is the ability to control the number and location of access points to a property. (Strafford Regional Planning Commission, n.d, pg.2)

Coordination of transportation and land use involves decision-making at multiple levels, and requires an interdisciplinary and integrated approach to combine the expert's opinion and viewpoints within the decision process. The Center of Environmental Excellence by AASHTO, recommends 'Vision Development' as the key step for integrating planning process. According to AASHTO,

> [d]eveloping a 'vision' and integrating planning processes and efforts for intermodal transportation and land use are often the first step towards more detailed planning, project development, and implementation. Visioning starts at the level of a region, transportation corridor, community, or neighborhood, and uses public and stakeholder input to reflect community values, goals, and objectives. The vision also serves as a basis for coordinating different agencies plans and policies, such as the long-range transportation plan, land use plans, a regional growth plan, local comprehensive or general plans, corridor plans, watershed plans, neighborhood plans, transit station area plans, local zoning ordinances, and conservation and environmental plans.

Some of the other planning approaches for coordinating the land use and transportation include local and regional planning approaches, which differ in their area of application. Local planning starts at the site or project level, responding to the needs of neighborhood or city level depending on the project scope, while regional planning requires thinking beyond project and jurisdictional boundaries when designating land uses. Both approaches differ in terms of their scope of work and public outreach. At the local level, transportation and land use integration is at implementation level, connecting development with the surrounding streets, sidewalks, transit facilities and other transportation infrastructure. While at regional level, the integration is at planning level, proposing integration in terms of station area plans, sector plans, and streetscape plans as projects (Transportation and Land use connections program, n.d).

At regional level, this integration requires active collaboration among public entities at all levels of government to determine "big picture" land development and preservation goals. Further, this approach highlights the crosscutting and multi-layered nature of land use issues. At the regional scale, decisions are made about where and how to grow in the long-term. Transportation priorities set at this scale shape the future decisions at city, corridor, and site scale. A regional planning decision combine a wide range of stakeholders-from local governments to grassroots advocacy groups and helps to streamline land and transportation planning processes to maximize efficient use of space. Some other strategies given below discuss integration methods in detail

Scenario Planning

Humans have always pondered the future and wondered how they might be able to anticipate change, particularly in areas over which they have little control. Scenario planning addressed those kinds of uncertainties (Schwartz, 1991). Zegras, C., Sussman, J., & Conklin, C. (2004) in their research paper state that - Scenario planning is not a replacement for traditional planning techniques such as forecasting; instead it aims to help organizations better prepare for the unexpected. In short, scenario planning helps to make robust strategic choices (2004, pg. 8). Michael Porter (2004) defines scenario planning as

> A scenario is an internally consistent view of what the future might turn out to be-not a forecast, but one possible future outcome (Porter, 1985, p. 446, as cited in Ringland, G., 2006)

The land use–transportation scenario planning practice that emerged in the 1990s essentially grafted the military and business approaches onto to the more customary planning structures of the continuing, cooperative, and comprehensive (3C) process. The practice was also a requirement by state and federal agencies including the Federal Aid Highway Act of 1962 and National Environmental Policy Act (NEPA; Bartholomew, 2005). The concept of scenario planning evolved because of disappointment with the traditional practice of using a single allocation of household and employment growth for transportation modeling and forecasting (Bartholomew, 2005).

The new method of scenario planning involves a combination of more traditional alternatives analysis with a new set of variables drawn from land use and transportation demand management.

Federal Highway Administration (FHWA) defines scenario planning as

> A process that can help transportation professionals prepare for what lies ahead. It provides a framework for developing a shared vision for the future by analyzing various forces (e.g., health, transportation, livability, economic, environmental, land use, etc.) that affect communities. (FHWA Handbook, 2010)

The technique evolved by and for use by private industry to anticipate future business conditions and for management of risk. FHWA considers it as tool for effective decision making from range of alternative future scenarios and prioritizing the needs rather then predicting the future. FHWA encourages transportation-focused scenario planning as

> An approach designed to help citizens and stakeholders in the public and private sectors understand the impact of demographic and land use changes on transportation networks in a state, community, region, or study area. (FHWA Handbook, 2010)

Bartholomew and Reid explain the method of scenario planning as

> Comparison of one or more alternative future planning scenarios with a trend scenario, where a trend scenario is past urban development and transportation investment patterns assumed to continue through the planning horizon (20 to 50 years in the future) with the newly formulated one or more alternative futures that consider integration of land use and transportation decisions for impacts on VMT and other regional outcomes. The alternative future planning scenarios have higher gross densities; mix land uses largely, and/or channel more development into urban centers. They may incorporate a variety of transportation infrastructure investments and pricing policies (Bartholomew, K., & Ewing, R., 2009, pg.2).

Bartholomew (2005) concluded in his 2003-2004 survey of MPOs that out of 152 recipients, about 45% indicated that they had at least some activity involving a form of scenario planning. Scenario-based planning allows for increased community involvement in planning. (Bartholomew, 2005, pg.14)

Lambert, J. H., Schroeder, M. J., & Ferguson, W. S. (2009) tested a methodology for analyzing the impacts of Virginia’s Long-Range Multimodal Transportation Plan, (VTrans2025) using scenario based assessment. The methodology includes identifying and selecting the regions and development scenarios based on key issues and factors affecting the region and evaluating their performance with respect to transportation policies. Scoring of transportation policies based on evaluation criteria allows an analysis of the significance of policy with moderate, or minimal/no influences each of the evaluation criteria. The weights are then assigned to the evaluation criteria within scenarios, providing the transportation planners and policy makers with an opportunity to assess the given the future scenarios in terms of their importance. A valuation in terms of policy performance sensitivity permits assigning a policy score, for each of several relevant regional future scenarios. This method gives an understanding for suitability of regions with preferred scenarios with respect to proposed policy impacts. (Lambert & et al., 2009, pg.13)

Scenario Planning for VMT and GHG Reduction

Scenario planning for GHG emissions reduction is a strategic planning process to establish a transportation and land use vision, goals and approaches for reducing greenhouse gas emissions. A scenario plan describes a general course for achieving the goal of reducing greenhouse gas emissions, rather than a specific set of actions that will be undertaken.

In 2005, the California Department of Transportation (CalTrans) developed a planning assistance program that provides funding to regions undertaking land use - transportation scenario planning analyses. Its importance is shown in the regional blue print planning reports as a program that enables public officials and other participants to more realistically evaluate future land use patterns and their potential impacts on the region's transportation system, housing supply, jobs - housing proximity and balance, environment and natural resources. (as cited in Bartholomew, K., & Ewing, R. 2010, pg.5).

The popularity of regional scenario analysis increased at about the time that researchers and policy makers began looking at the roles that land use development patterns play in contributing to the nation's overall emissions of greenhouse gases (GHGs). Residential development and the auto travel associated with it comprise almost 40% of U.S. CO2 emissions (EIA, 2008).

Scenario planning for GHG emissions reduction evaluates combinations of land use development alternatives and transportation system alternatives to identify a plan and actions to reduce GHG emissions. The benefits that the development alternatives can offer are calculated by comparing the alternative scenario to a "trend" or "business-as-usual" case estimate. It is possible to explore how alternatives for accommodating growth could affect people's travel, amount of VMT, and the resulting GHG emissions. (MPO GHG Task Force Report, 2010, pg.12)

Many cities and MPOs are working towards establishing an integrated land use and transportation scenario planning and visioning tool to reach the goals of reduction in GHG and VMT. Recent state level policy initiatives like California's Senate Bill 375 (2008) and Oregon's House Bill 2001 (2009) and Senate Bill 1059 (2010), now require MPOs to incorporate GHG emission reduction strategies into their federally required long-range transportation plans. Apart from scenario planning, other design and standard policy based approaches like context sensitive solutions, access management techniques have been explored to provide an integration of land use and transportations decisions to some extent.

The FHWA supports many tools, programs and approaches that support integration of land use and transportation planning initiatives. Various initiatives like the scenario planning, context sensitive solutions, access management, role of visualization in transportation planning, etc assists the state and local decision making bodies to improve and enhance the transportation projects and its related aspects. (FHWA, 2012,para.1) Methods like context sensitive solutions, access management is discussed in detail in the following section to understand their contribution towards the process of land use and transportation integration.

Context Sensitive Solutions

According to the FHWA –

> [c]ontext sensitive solutions (CSS) are a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist. (FHWA, 2012, para.7)

CSS looks at a transportation project in the broader community context and involves citizens from the early stages of planning. The goal of CSS is to ensure that the design of a transportation project achieves the community’s goals for the neighborhoods (natural or human) bordering the road (the context in which the road will exist), and that the road serves as an asset, not as a degrader, to the land beyond the pavement.

CSS enables road planners to customize a road design to its surrounding context; for example, when a high-speed suburban road enters a community, a neighborhood, or some other walkable district, to change into a more human-scaled design that causes cars to drive slower and creates a walkable, pedestrian-friendly urban environment. CSS can apply to the planning of a new road, a road widening, or rehabilitation or retrofit of an existing one. One way of ensuring CSS and the link between transportation and goals for land use and community character is to prepare a neighborhood plan (also called a corridor plan) for the area that borders a road before designing the improvements. In that approach, the plan provides the framework for planning a road improvement design to allow accessibility of vehicles, and meet the objectives of the neighborhood and create a place of lasting value. (CUES, n.d, para.2) CSS approaches have been successful in integrating issues like cultural and historical resources and their associated land uses to transportation planning projects. However, the CSS approach is very useful when working on community level, but when it comes to integrating the land use and transport decisions at regional scale, the CSS approach may require a lot of data and input for the desired results.

Access Management

Access Management is a term used by transportation professionals for coordination between roadway design and land use to improve transportation. According to FHWA,

> Access management is proactive management of vehicular access points to land parcels adjacent to all manner of roadways. (Access Management– FHWA, (2012, para.5)

State and local agencies have worked to control access to properties along major roadways to improve traffic flow and safety. Access management principles include restricting uncontrolled driveway access onto major arterials, restricting left turns, providing internal connectivity among properties, and providing adequate access on connecting streets to avoid traffic conflicts. Different levels of access management approach is applied based on street classifications and/or area land use designations, to ensure that the principles applied are both consistent with the function of the transportation facility and respect the character of the land uses and neighborhood served.

Access Management involves changing land use planning and roadway design practices to limit the number of driveways and intersections on arterials and highways, constructing medians to control turning movements, encouraging clustered development, creating more pedestrian-oriented streetscapes, improved connectivity, and road space reallocation to encourage efficiency. Although access management provide proactive management of vehicular access points to land parcels adjacent to all manner of roadways. Good access management can also promote safe and efficient use of the transportation network (FHWA – Access Management, 2012, para.1). It can also support transportation demand management by integrating transportation and land use planning, and by improving transportation options. It can help convert automobile-oriented strip development into more accessible land use patterns that are better suited to walking, cycling and public transit.(Litman, 2011)

While scenario-planning method aims to integrate, land use and transport decisions mainly using a future prediction method with a vision, strategies like CSS and access management aims to improve the transportation projects in context with the surrounding land uses, by providing an overall view of the proposed projects with environment. Land suitability analysis is another approach aimed at providing an overview of the proposed land use in future; it provides an opportunity to analyze the effectiveness of the proposed land use on the surrounding. The next section discusses the concept of land use modeling and suitability analysis in detail, as the research uses the LUCIS framework for the ultimate goal of the study, which is land suitability based analysis.

Land Use Modeling and Suitability Analysis

Concept of land suitability: In a general term, land-use suitability analysis is a process of identifying the most appropriate spatial pattern for future land uses according to specify requirements, references, or predictors of some activity (Collins, 2001, p. 611; Malczewski, 2004, p. 4). The concept of land use suitability is functional to many areas of environmental, ecological and water shed planning.

Late Ian McHarg, Professor of Urban Design and Landscape Architecture, at the University of Pennsylvania, successfully developed the concept of suitability. In his famous book 'Design with Nature' (1969), McHarg explains the concept of using overlays, which is a set of drawings used as "layered" overlay sets, photographic combinations that show all of the characteristics associated with locations on a map. He also explains it as a process of mapping the individual elements and then photographing these as transparent prints.

Some of the ancient techniques of using overlays described by McHarg are still acting as a base for producing the suitability maps, with the technological help of geographic information systems (GIS) today. The older method involved mapping data on the natural and human-made attributes of the environment of a study area, and with use of individual, transparent maps and using light to dark shading (i.e. high suitability to low suitability) with overlays by superimposing the individual transparent maps over each other to construct the overall suitability maps (Malczewski, 2004, p. 5). Overlaying of maps is the central theme in GIS applications today, where a GIS is defined as ‘a system that integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (ESRI, n.d). The spatially referenced layers in GIS replaces the hand drawn individual maps, and are easily super imposed on each other to create GIS suitability maps.

GIS serve the multi-criteria evaluation function of suitability assessment well, providing the attribute values for each location and both the arithmetic and logical operators for combining attributes (Jiang and Eastman 2000). Whereas, the MchHarg’s method of overlays and suitability analysis used vector-based data i.e. lines and polygons, the use of GIS based suitability analysis provided more accurate results with use of raster based data. According to the Environmental Systems Research Institute (ESRI) who develops and provides GIS mapping solutions, a raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid), where each cell contains a value representing information. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps. (ESRI, n.d)

In general, the GIS-based land suitability analysis assumes that a given study area is subdivided into a set of basic unit of observations such as polygons or rasters. Then, the land-use suitability problem involves evaluation and classification of the aerial units according to their suitability for a particular activity (Mokarram and Aminzadeh, n.d). Currently a number of GIS-based tools and software are available based on McHarg concept. The following section discusses various GIS based tools in detail to understand their potential benefits and limitations.

GIS Based Tools for Integrating Land use and Transport Decisions

The FHWA Web site, called the Toolbox for Regional Policy Analysis, outlines a variety of analysis methods useful in transportation planning and in evaluating the impact of land development patterns on transportation plans and projects. The FHWA defines the term "land development" as conversion of land for the purposes of residential, commercial, industrial, or other activities and pertains to the amount of land by type of use in an area, as well as the characteristics of the development (e.g., residential density).

Their typology of methods for forecasting land development patterns includes proximity forecasting, Delphi/expert panel, accessibility based forecasting, simple land use models, and complex land use models. Proximity- based forecasting relies on regression models that project development patterns based on the proximity of past development to transport facilities and other urban infrastructure. The Delphi or Expert Panel is a group of local experts gathered to predict the impact of land development pattern. For example, the Delphi method was used in Wisconsin with a panel of experts, to assess the potential land use impacts from State Trunk Highway 26.

Another method known as the accessibility based forecasting uses quantitatively based accessibility measures derived from a travel models used to forecast development. Simple land use models are simple zone based land use models using sets of equations to forecast land development with limited amount of data for model calibration and inputs. Accessibility is a primary driver of development in these models; however, other factors may also be included depending on data availability.

While, the complex land use model as the name implies, this has combinations of land use model that interfaces with an existing travel model, or an integrated urban model with land development and travel models together. This model spans an entire metropolitan region with a zonal structure, similar to travel demand models. Consistent with region-wide forecasts of population and employment, these models allocate development to each zone based on transportation accessibility, land prices, available land by development type, and/or other parameters. The models are typically calibrated using historical data on land development, prices, transportation accessibility, and other factors. DRAM/EMPAL is the most widely applied model in the U.S. (FHWA – Impact methodologies, n.d)

A number of GIS-based models based on the principles of smart growth strategies are available for helping communities create their alternate future scenarios and helping them in identifying the issues and in visualizing future scenarios. With the advancements in the technology, the ability to conduct scenario planning has changed radically within the last several years. A number of GIS tool have emerged in the market that allow users (mainly local governments or non-profit agencies) to undertake “real-time” scenario planning exercises within the space of a single evening. Some of the these tools include software packages distributed under names, such as PLACE^{3}S, CommunityViz, INDEX®, EPA Smart Growth Index, GB-Quest, and Smart Places. These software or packages permit users to input scenarios, either graphically or numerically, and observe the projected impacts of their assumptions almost instantaneously. The following sections explains some of these software packages for scenario planning, selected on the basis of their capability for producing realistic scenarios.

Community VIZ

CommunityViz is a GIS software package designed to help communities create alternative future scenarios by helping people visualize, analyze and communicate about the future and is widely used across the United States. Since this is a GIS-based decision support tool too, it helps in understanding the development impact of plans and proposal by comparing existing and potential scenarios, predicting the impacts of probable changes through visualization. The software visualizes issues like changes in economic scenario, effects on wildlife habitat, and the influence of transportation development effectively. The software provides outcomes at varying scales and includes a 3D modeling package to allow visual display of outcomes.(Orton Family Foundation, 2009)

IPLACE^{3}S

The PLACE^{3}S method (Planning for Community Energy, Environmental, and Economic Sustainability) is both a planning approach and GIS-based analytical tool to support community land use and transportation planning. (FHWA- Toolkit for integrating land use and transportation decisions, n.d)

The method includes five-step alternatives analysis that includes public involvement, design and impact measurement in each step with coordination of planning activities like the regional transportation process. PLACE^{3}S is GIS-based analysis tool that provides information on impact measurement and relies heavily on availability of data. This method is effective to develop alternate site or area level development patterns using the GIS-based software and tool, from which variety of measure can be calculated for each development scenario such as:

- Auto dependency-VMT per capita, mode shares;
- Housing/transit proximity-percent of dwellings within one-quarter mile of a transit stop;
- Air pollution-criteria pollutants emitted from all sources;
- Redevelopment readiness of major parcels, measured as the difference between the value of the land and its improvements;
- Recreational land supply-acres of parks per 1,000 residents;
- Solar friendliness-percent of street centerlines lying within 30 degrees of an east/west axis line; and
- Global warming-carbon dioxide emitted from all sources, in pounds per resident per year. (FHWA- Case Studies for IPLACE^{3}S ,n.d)

California urban futures model

The California Urban Futures Model, second generation (CUF-2) is an advanced model that uses the alternate scenario development technique with use of GIS and predicts future development based on land use policy. It is based on the first generation model (CUF-1) originally designed for the Northern California Bay Region, and takes into account past development trends, land characteristics, user-input policies affecting development patterns, user-defined land use categories, and allocates population (residential and employment) accordingly developable land units or DLU's.(TRB , 2009)

Land use conflict identification strategy (LUCIS)

Margaret Carr and Paul Zwick (2007) developed the Land-Use Conflict Identification Strategy (LUCIS) model over a ten-year period instructing students in a joint studio called the Ecological Design Practicum in the Department of Urban and Regional Planning at the University of Florida. LUCIS is a goal-driven model that attempts to derive probable future land-use patterns based on the three broad land-use categories of agriculture, conservation and urban. The LUCIS develops alternative land-use futures based on three categories mainly, called suitability, community preference and conflict' (Carr and Zwick, 2005). It uses spatial data to represent land use pattern and identifies area suitable for growth depending on the goals and objectives, comparable to the conflicting land uses present or proposed. It reflects the idea that the land use is most acceptable when allocated in areas of high suitability and lowest conflict for most planned and predictable scenario.

The results of the analysis can be used as a decision support tool in future land use planning, environmental planning, or allocation of future land use (Carr & Zwick, 2005). Six steps are involved in the LUCIS process as defined by Carr & Zwick (2005) as:

1. Goals and Objectives: Define the criteria for determining suitability by creating a set of goals and objectives.
2. Inventory: Create an inventory of data related to the goals and objectives.
3. Suitability: Analyze the collected data to determine the suitability of the goals and objectives.
4. Preference: Combine the suitabilities of each goal to determine preference.
5. Collapse Preference: Collapse the preferences for each land use into three ranges of high, medium, and low.
6. Conflict: Compare the preferences ranges to determine areas of conflict.

The various methods discussed above provide a comprehensive understanding of the preparation of alternate scenario tools available. Depending on data availability and technical resources, the metropolitan regions with their future goals and visions can adopt an appropriate method. The following section discusses a policy-level perspective of linking land use and transportation for GHG reduction in making long-range plans with on overview of policies and strategies adopted in the various states, focusing the state of Florida.

Summary of Literature Review

With growing concerns over the lack of physical activity, increase in greenhouse gases, and other threats to sustainability, planners, engineers, and policy makers are looking for ways to increase the integration of land use and transportation decisions. It is widely known that land use and transport interact with each other and the present land use pattern and transportation system is decades old as a result of several development options in past which cannot sustain the future development pressure for long.

In the U.S., MPOs play a critical role in deciding the future of regional transportation planning. However, the impact of transportation corridors and development can have impacts beyond the metropolitan area into outlying areas and neighboring cities. These transportation decisions are complicated because of the role of land use patterns that have developed organically based upon the adoption of a particular transportation system. Thus, even where there are structures for regional governance, there is a need to better integrate land use and transportation decisions. This includes spatial and temporal issues related to land use and transportation investment decision-making. The institutional arrangements for transportation and land use integration are a vital topic for further research. These institutional arrangements include structures created through legislation (e.g., MPOs), administration (e.g., regional transportation organizations), and less formal mechanisms (e.g., coordinating committees). Although institutional arrangements in the form of regional governance is not the central theme for this research, the data gathered for proposing LUCIS based future scenarios can be helpful in making the regional governance more effective for integration of land use and transport decisions.

The literature reveals that much research has been completed that reinforces the importance of integrating and understanding the relationship between urban form, transportation, and recent global environmental concerns about climate change and crude oil shortages, yet there is still a need for research on adaptive solutions for effective outcomes. The issues like increased VMT from land use and transportation projects, with need for public transit have changed the direction of government policies and planning strategies forcing the local government to adopt strict regulations and reduction targets. However, this has given rise to even more concerted research in this area, as to which future prediction method will be more closely associated with appropriate development pattern. As seen in the literature, various methods of integration and scenario forecasting methods are available; however, there is still a need for research on selecting appropriate future prediction methods with consideration for right tools. The literature shows that there is still a considerable gap in the knowledge of how land use and transportation systems should be managed in order to promote a future, which is sustainable for the coming generations so that the projected development in the future is free from any negative social, economic and environmental impacts.

The Chapter 3 details the background study for the various policy initiatives undertaken in the United States of America, focusing on the State of Florida, accompanied by three distinct case studies who have successfully integrated the land use and transportation planning for future scenarios.

CHAPTER 3
BACKGROUND RESEARCH FOR POLICY INITIATIVES AND DESCRIPTION OF CASE STUDIES

Overview of Policy Initiatives

There is no doubt that transport decisions and land use development go hand in hand. However, in last few decades, the federal and state policies have played an important role in strengthening the connection between transportation funding and land use planning.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 ended the focus on building the interstate highway system and made it possible for communities to use federal transportation money on a broader range of transportation investments to promote planning for all modes of transportation, also known as multi-modal transportation planning (Smart Growth America, n.d). The multi-modal transport system refers to a system that offers users diverse transport options that integrates effectively in order to provide a high degree of accessibility even for non-drivers (Litman, 2011, pg.13). Since ISTEA, the federal government has instituted several programs to channel transportation funds toward TOD, traffic calming, livability measures, and other projects that promote a balanced travel mode split and community safety. Federal programs such as the Transportation and Community and System Preservation (CTSP) Pilot Program, the Transit Enhancements Program, and the New Starts Program provide funding to states, local governments, and MPOs to investigate and address the relationship between transportation and community and system preservation. (Binger, G., Lee, R., Rivasplata, C., Lynch, A., Subahsini, M., 2008)

Climate Change Initiatives

The land use planning integration with transport decisions are also important from an environmental perspective, as there has been consent about the future risks of climate change associated with transportation activities initiated by land use planning and the immediate concerns about air quality in many cities. The Intergovernmental Panel on Climate Change (IPCC), identifies the potential damages and impacts of transport related climate change, due to increasing GHG emissions and recommends that a a reduction of 50% is required by 2050 in order to limit the temperature change by 2 degree. Many countries are developing reduction targets and strategies to overcome the impacts of GHG emissions. (OECD/ITF Working Group, n.d)

In United States, more than 30 states have developed climate action plans and are associated with various state and local initiatives like the clean cities coalition. Among the State actions for reducing GHG from the transportation sector, California has been a pioneer in passing legislation called AB 32 (the Global Warming Solutions Act of 2006) that established a goal to reduce the state's greenhouse gas emissions to 1990 levels by 2020. Until now, forty-two states have compiled GHG inventories and forecasts and seventeen states have set GHG reduction targets. The inclusion of climate change considerations in the long-range transportation planning process as a part of regulatory frameworks occurs in only a few states, as only few state DOT's are presently engaged in climate and energy planning as part of the long range planning process (Burwell, 2005, pg.16). California can be seen as the most advanced in its integration of land use and transportation decisions for reducing VMT and climate change.

Case of Florida

With a long history of growth management planning, Florida first addressed growth management through two land use programs in 1972: the Environmental Land and Water Management Act of 1972. The act of 1972, provided for state designation of the Areas of Critical State Concern (ASCS) [Florida Statute 380.05] and defined the *Developments of Regional Impact* (DRI), providing for heightened regulation in the planning and approval of very large developments that affect more than one county. [Florida Statute 380.06] (Carriker, 2006, pg.2)

In 1975, the state passed the Local Government Comprehensive Planning Act, requiring comprehensive plan for all levels of local government. By 1982, 419 of 461 cities and counties had adopted comprehensive plans, and by 1984, all local governments had adopted plans reviewed by state agencies. Concerns about the quality, consistency, and implementation of these plans led to the 1985 Local Government Comprehensive Planning and Land Development Regulation Act and the Omnibus Growth Management Act, which requires all municipalities and counties to create local comprehensive plans. In 1986, a statewide Comprehensive Plan was adopted to outline goals for local action plans. (Binger et al., 2008 pg. 39)

In 1999, the Florida legislature amended Chapter 163, Florida Statutes, commonly known as the Growth Management Act, authorizing local governments to establish multimodal transportation districts. The purpose of the legislation was to provide a planning tool for communities in Florida that reinforces and supports community design elements like walking, bicycling, and transit use. (FDOT, 2004, pg.1)

In 2005, the state enacted legislation (SB 360) that amended the 1985 Growth Management Act to promote urban scenario modeling to integrate land use decisions with transportation, offering incentives for local governments to adopt 10-year urban service boundaries, and requiring workshops and public meetings for a “visioning” process that must precede boundary designation. (Binger et al., 2008, pg.41)

In 2006, State of Florida also passed a legislature for its first comprehensive energy plan. Later in 2007, Governor Charlie Crist of Florida took three actions that propelled Florida to the forefront of states actively working to address climate change. State agencies prepared the Florida Energy and Climate Change Action Plan, and he signed two Executive Orders (EO’s) – EO 07-126 that direct the state to adopt GHG reduction policies and EO 07-127 that set the GHG reduction targets for the State of Florida. The 2008 Florida Legislature adopted two significant pieces of legislation to help implement Governor Crist’s climate change initiatives - HB 7135 and HB 697. Both bills add new requirements affecting energy efficiency, land use planning, and building standards.

As discussed above, various states have enacted their programs for reducing the GHGs at state and regional level, including planning and growth visions with long-range plans with GHG reduction targets. Understanding the development of policy initiatives in state of Florida provides an overview of the efforts towards the climate change and integration of land use and transportation decisions. Long range planning in Florida, provides the policy level background, which is important for conducting this research study that aims at analyzing the prediction methods for long-range plan.

The next section discusses case studies pertain to efforts for reducing GHG emissions by various agencies for long range planning. The three case studies were selected for understanding the state and regional efforts on making long range plans with GHG reduction targets and using scenario planning methods for integrating land use and transport decisions.

Case studies that integrates land use planning and transportation

The following case studies were selected for understanding the various efforts undertaken to integrate land use and transportation planning in long range planning to create a sustainable strategy for future.

Envision Utah

Envision Utah is a public-private partnership founded in 1997 to research growth scenarios for the Greater Wasatch Area, and to provide guidance on future development. Envision Utah is a result of involvement of various stakeholders and an in depth value analysis of residents. Quality Growth Strategy is a planning vision developed through an extensive public outreach process that was developed based on goals like walkable and sustainable communities and TOD.

The Quality Growth scenario includes an expanded transit system, a higher proportion of multi-family housing and small-lot homes, and greater clustering of new housing in villages and towns along major roads and rail lines. Based on the Strategy, Envision Utah has supported efforts in the Greater Wasatch Area to enhance mobility, provide a diverse supply of housing and employment options, improve air quality, maintain water reserves, and protect open spaces. Envision Utah works with private developers, state and local leaders, and private citizens to encourage the prioritization of alternatives that promote livability and community preservation.

The Mountain View Corridor Environmental Impact Statement (EIS) is one of the most practical and successful application and was initiated by Envision Utah and the Utah Department of Transportation in a process called Growth Choices. These two state agencies collaborated with City of Salt Lake/Salt Lake Region addressing land use and transportation solutions in high growth corridor in a phased approach, by combining roadway, transit, and land use commitments from all participants. (NCHRP 8-36-8, 2008, pg. 8)

SACOG blue print project

The most widely cited success story for scenario-based integration of land use and transport decisions that focuses on reducing GHG and VMT, is the Blueprint Project of Sacramento, California. The Sacramento Council of Governments (SACOG) adopted it in December 2004, and called it the ‘Preferred Blueprint Scenario’ - a vision for growth that promotes compact, mixed-use development and more transit choices as an alternative to low density development (SACOG, 2007). In 2008, the SACOG Board adopted the Metropolitan Transportation Plan for 2035, using the Preferred Blueprint Scenario as the basis for the making decisions about land use and transportation investments. The Metropolitan Transportation Plan for 2035 links land use and transportation planning, with $42 billion in transportation investments, in the six-county Sacramento region over the next 28 years. (SACOG, n.d)

Preparation of the Sacramento Regional Blueprint was driven by concern about using recent or current trends to support dispersed future growth patterns, housing, transportation, air quality, and insufficient land to accommodate expected growth by 2050. MTP2035, prepared by SACOG, is based on the need to link transportation planning with land use by creating a vision for future land use in the region to create and fund a transportation plan that serves the long-range transportation needs of the region.

The development of preferred scenario blueprint used a bottom-up process, starting at the neighborhood level with the residents’ viewpoints on “business as usual” development scenarios and concerns. The alternatives future scenario uses the PLACE3S GIS modeling program for assessing its impacts. Four countywide scenarios (a trend scenario plus three alternatives) were constructed for each of the region's six counties based on the public participation process to analyze their impacts.

These twenty-four scenarios formed the base for creating four regional scenarios, among which emerged the Preferred Blueprint Scenario, which projects smaller urban footprint and 26% fewer VMT than the trend scenario at the planning horizon. (Bartholomew, K., & Ewing, R., 2009, pg. 32)

Gainesville (Florida) MTPO 2020 long range transportation plan

In 2000, the Gainesville Metropolitan Transportation Planning Organization (MTPO) adopted a 2020 Long Range Transportation Plan (LRTP), also referred as the Livable Community Reinvestment Plan. This plan was developed using the scenario planning approach, and the plan adopts best elements of the compact, radial, and town/village center alternatives and integrates them into a land use/transportation needs plan for the Gainesville area.

Every five years, the State of Florida requires all Florida MPOs, to update their LRTP's. While preparing for its 2020 LRTP, the leadership in the Gainesville region indicated growing concerns about possible high growth rates during the planning period. The agency identified and addressed specific challenges including lack of street connectivity, uncomfortable streets for walking and bicycling, suburban sprawl development patterns and unbalanced growth, impacts to existing neighborhoods and changes in town character, preservation of natural resources and habitat, limited travel options, inadequate bus service coverage, and traffic congestion/safety on major roadways in the 2020 horizon period.

CHAPTER 4
STUDY AREA

Introduction to Region

According to 2010 Census data, most of the Florida's largest counties and cities grew more rapidly than nation since 2000, reports of 2010 shows in an online article - 'Florida growth outpaces national trend' published by USA today that,

> The census reports that despite record foreclosures and high unemployment, Florida still grew 17.6% to 18.8 million, well above the 9.7% national rate. (Nasser, 2011)

In addition to the coastal Florida region, which continues to grow, demographers are expecting a growth in the central or inland Florida region due to presence of favorable natural surroundings and viable economic growth. The growth rate may be slower than experienced between 2000-2006, which was fueled by booming economy, and growing housing market (Smith, A & Rayer, S.,2011)

Heartland in Central Florida

The Heartland region which is located in the central region of the State of Florida and is composed of the seven counties of Desoto, Glades, Hardee, Hendry, Highlands, Okeechobee, and Polk (Refer Figure 4-1 for detail map of the Heartland region). Out of the seven counties, Polk and Higlands County are the most populated in the region. Florida's Heartland faces both serious threats to maintaining its traditional agricultural economy, and accommodating the future growth.

The seven county Heartland Regions has substantial rural and agricultural areas affected by growth pressures. These growth pressures can provide new markets and job opportunities or lead to the loss of vital agricultural production. However, they also make it necessary to plan for adequate transportation systems for both the region and connecting to statewide corridors.

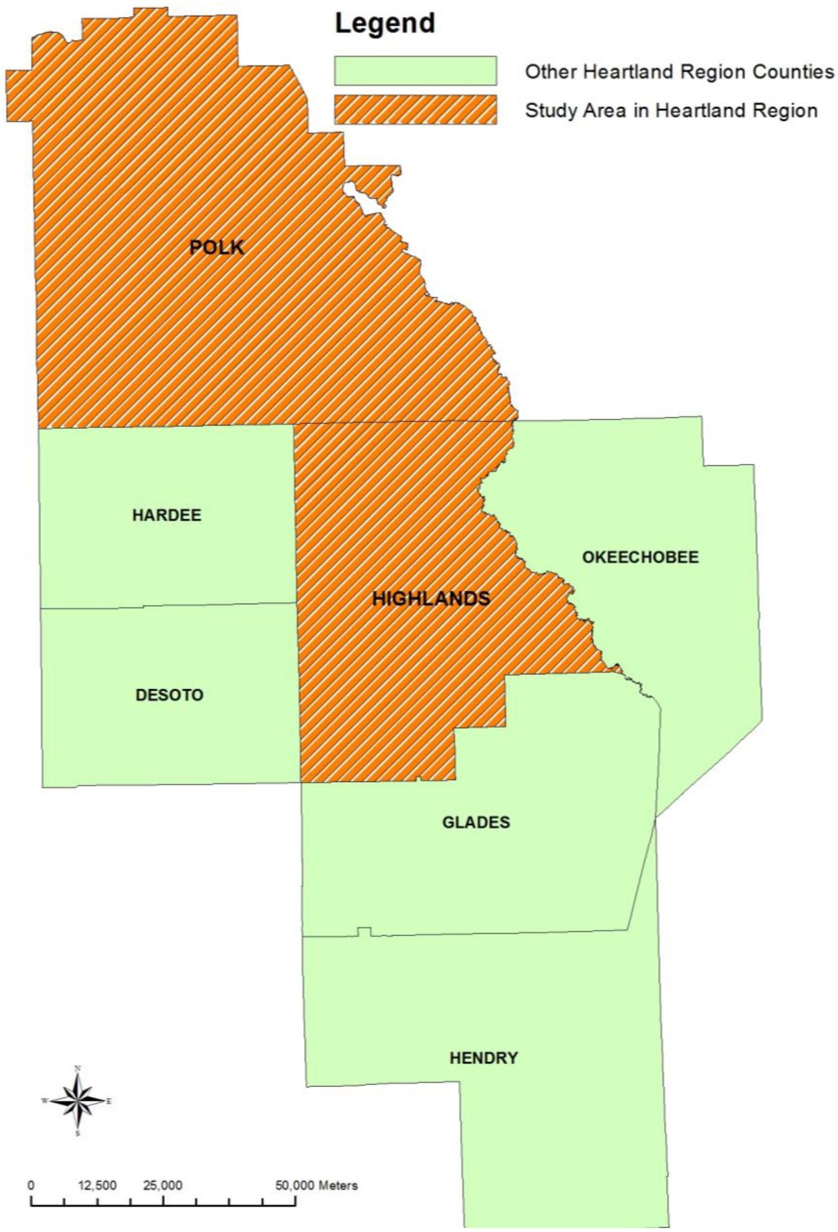


Figure 4-1. Florida's Heartland Region showing all seven counties, Map courtesy of Author

Florida's Heartland contains ecologically significant land including wildlife and rare plants. It has river basins nourishing the Charlotte Harbor National Estuary and Lake Okeechobee and the Everglades. Long range planning must consider protection of the vital natural resources while linking adequate transportation systems and land use patterns.

About Study Area

The study area limits to Polk and Highlands County of the Heartland Region in the Central Florida Region, which also comes under the Central Florida Regional Planning Council (CFRPC). The Central Florida Region, which is the state of Florida’s most diverse region, comprises of three sparsely populated rural counties - Desoto, Hardee, and Okeechobee, Highlands- a small, moderately populated rural county, and Polk, one of the counties in the State with the largest land area.

Polk, with the two largest cities in the region, Lakeland and Winter Haven, has a population almost three times the rest of the region, and is one of Florida's twenty most populated metropolitan areas. Most of the region is rural in area, except for the Lakeland/Winter Haven Urban Area in north central Polk County, which is home to approximately 40% of the Region's population. Polk County is an inland, urban county, the largest county in dry land area in the state with 1,875 square miles and population of 602,095 as per 2010 census with a projected population of 932,300 in 2040 as per the CFRPC region. Seventeen municipalities are in the County, ranging in population from Lakeland with 74,626, to Highland Park with 157 persons. The unincorporated areas of the county are growing 3.6 times as fast as the population of all the municipalities. Even though Polk County is urbanizing, citrus, cattle and phosphate mining are still important. (Polk County, n,d)

Figure 4-2. Study Area showing Polk and Highlands County, Source: Map Courtesy of Author

Polk County produces more oranges annually than California, but in the last five years, the market value of prime citrus land has fallen from near $20,000 per acre to barely $10,000 an acre for the same groves. Polk County is also the economic engine of the central Florida region with approximately 75% of total personal income in the region is accounted for by Polk County alone.

Highlands County is an inland, rural county with a single major urban area, the Avon Park/Sebring Urban Area, which includes Avon Park, Sebring and Lake Placid and is located in the central section of the county along the U.S. 27 corridor. According to the 2000 census, the county has a total area of 1,106.28 square miles (2,865.3 km^2), of which 1,028.27 square miles (2,663.2 km^2) (or 92.95%) is land and 78.01 square miles (202.0 km^2) (or 7.05%) is water. The 2010 population of the Highlands County was 98,786 with a projected population of 129,000 in 2040. The populated areas of Highlands County do not qualify as an urban area for purposed of U.S. Census statistics, but it has a large enough population to support a regional mall and regional cultural activities. Highlands County also produces citrus, farm crops and beef, but has no phosphate reserves (CFRPC, n.d).

The Highlands County is an inland county, surrounded by Polk County in the north, Desoto and Hardee County to the west, Okeechobee County in the east and Glades County in the south. In Highlands County residents enjoy the highest per capita income of any county in the region; however, more than half of the total personal income in Highlands County contributes from "non-labor activities", and its per capita income is less than 83% of that of the State of Florida. Highlands County contributes to second place with 13% of the region's economic base.

Table 4-1. Population of counties in Heartland Region

County	2010 Population	2001 Population	Percentage Change
Highlands County	98,786	87,386	13.1
Polk County	602,095	483,924	24.4
Desoto	34,862	32,209	8.2
Glades	12,884	10,576	21.8
Hendry	39,140	36,210	8.1
Hardee	27,731	26980	2.9
Okeechobee	39,996	35,910	11.4

Source: Census 2010

The other counties of the Central Florida Region are Desoto, Glades, Hardee, Hendry, and Okeechobee, along with Highlands County, the region is also known as the South Central Florida Rural Area of Critical Economic Concern (RACEC) The region continues to experience economic distress, including extraordinary unemployment rate (FDOT - REDI, 2010, pg.7)

Criteria for Selecting Study Area

As the heartland region continues to grow in coming decade, challenging the state and local level agencies for accommodating the growth and handling the development pressures with economic constraints. Polk and Highlands County in the Heartland region provide a good case, as they are the representatives of these challenge-facing counties in such an environmentally sensitive region with a changing economy due to development and growth pressure. The study areas for this research also provide a good case study for several reasons. Firstly, the combination of both counties represents the most populated counties of the region, making it challenging to predict the development pattern for the projected population. Secondly, the counties together also represent the financial capital for the Heartland Region, acting as an attractive place for future residents and creating challenges in accommodating the growth. In order to achieve a more balanced transportation system for future growth and balanced economic development, both counties need better transport options along with integration of land use and transportations. Simultaneously, the county also need to take appropriate measures to conserve the natural ecosystem from potential growth; all of these factors make these counties good case studies to analyze an alternate land use scenario in comparison to the one predicted for the region.

Thirdly, According to the research project - Florida 2060 by Geoplan Center, at University of Florida, sponsored by 1000 friends of Florida, Polk County will develop completely by 2060, and is likely to have spill over development in the surrounding counties. Therefore, Highlands County's adjacency to rapidly growing Polk County creates opportunities for population growth to “spill over” into Highlands County, creating challenges for the coordination of transportation and land use decisions and integration within and between both Polk and Highland County.

Fourthly, the study area provides an ideal base to study the impact of VMT on a region and the options for transit in a region forecasted to grow rapidly in future. These factors provide an opportunity to analyze the policies and plans necessary to integrate land use and transportation to reduce VMT and GHG emissions.

CHAPTER 5
METHODOLOGY

Creating Alternative Scenario of Future Development in the Study Region

The LUCIS based future scenario for growth in population and employment will help in analyzing the situation spatially in the study region and will provide a comparative analysis of expected deviations or similar trends from the current projected growth. This is very important for the framing of long-range plans as guidelines to the future development as it decides the growth direction.

For the selected study region, this study created an alternate development scenario using compact development and focusing on integrating transport and land use decisions. The alternate scenario uses the LUCIS methodology and guidelines from the individual county long-range transportation plan, as well as the Heartland 2060 project, for which these are the two largest counties in the entire project area. The LUCIS based future scenario mainly depicts a scenario, which strongly promotes compact development focusing on reducing the carbon footprints. The scenario also promotes viable economic development options as it aims to promote a multi-modal corridors and transit service like an express/rapid bus service, which can provide an easier affordability within the region, as the region faces vital economic crisis, along with compact development and mixed use development.

The use of main transit corridor as spine for development also depicts a scenario for future with reduced VMT reducing the carbon footprints and conserving the natural areas by reducing the sprawl in term of compact development. The scenario does not take in to account any secondary road development, and focus of development is restricted to the buffer areas around the transit route and transit stops. This provides a comparative analysis of the present base case scenario predicted by the LRTP for each county to the LUCIS based future for compact development, demonstrating differences in land area consumption as well as type of land affected by urbanization patterns.

Study Time Frame

The period for this study is determined as the year 2007 to 2035, which is based on the availability of relevant data and for the planning horizons covered by the policy documents for the Polk and Highlands County used in the study. The most current available data for the study area is for year 2007, which is the base year for the scenario prediction of the long-range plan. Since, the research creates an LUCIS based future scenario for the two counties, same base year data is used. The end-year of 2035 predicted for the scenario accounts for following factors.. Firstly, the period for the planning period for the long range plans for the Polk and Highland County are predicted for 2035, which are also the base for predicting a 2060 scenario.

Secondly, the transportation demand model (TDM) used in the study, which creates scenario for the individual counties is projected for 2035, which also utilizes the socio economic data and forecasts for 2035. Thirdly, at the commencement of this study the most current mobility vision plan for the counties is for the planning period 2035. Lastly, projected population and employment data for all of Florida's counties was available from the University of Florida's Bureau of Economic and Business Research (BEBR) is available from 2009 -2035, which is the last year. Since the main policy documents guiding this study describe plans up to the year 2035 and that a TDM for the individual counties pertains to the specific year, which uses data created by one of the methods under investigation, 2035 is deemed as most appropriate year to end the study period.

Overview of Methodology

The research uses the retrospective –prospective study design and creates alternate growth scenarios for the two county region using GIS in LUCIS framework and compares it with the results from the base line scenario generated for both the counties as described in their respective LRTP using a different projection method.

The alternate future scenario (as referred to scenario after here in the report) use projected population in the form of estimated growth for the selected period i.e. 2035 for both Polk and Highlands County and allocates land required for accommodating future population. The scenarios allocate future land use and population in the form of growth along the proposed transit services in the county (Highlands County proposes bus services, while Polk County proposes a light rail and express bus service for 2035 scenario). The scenarios also uses proposed transit stops/activity centers on the transit routes, as growth centers and these centers identified for both counties respectively is a result of long-range transportation plan documents. These activity centers or a landmark identified on transit stops uses the assumption that in order to promote compact growth, the stations can provide easier accessibility to residents for the transit services.

The Polk County Mobility Vision Plan for 2035 (2035 MVP) uses a center scenario analysis, which involves analyzing growth near the major activity centers identified as) probable future transit stops for the 2035 transit route (Appendix F- Polk County 2035/2060 Population and Employment Forecasts. pg. 47) for assessing the probability of TOD. The 2035 MVP proposes that the growth can be allocated in the form of radial distances along the transit stops like one quarter mile, half-mile (TOD distances), three-fourth of a mile and 1 mile. The research study utilizes same location of activity centers and same distances as buffers along the proposed transit stops in the land use modeling for the Polk County region. However, the location of transit stops is restricted to the proposed transit route only.

The Highlands County LRTP does not identify any transit stops / activity centers for its proposed transit route as shown in the transport model. In absence of any data related with transit stops for future for the Highlands County, the study created its own data for transit stop using the following method. Firstly, major landmarks/activity centers on the proposed transit roads was identified (proposed transit route as identified by the Highlands County) using the parcel data and available Highlands County GIS data. The base assumption for doing this was that these activity centers or major landmarks could serve as the location of future transit stops like bus stops etc for easy accessibility in the area.

The allocations of population for the scenarios for both counties were restricted to the buffer areas around the transit stations in the form of concentric circles. The guidelines for establishing the buffer distances were derived from the center scenario analysis used by the Polk County TPO for the long range plan for 2035 (Appendix F, 2035 MVP). The list of buffer distances used along with its method of creation is detailed later in the Chapter 5.

The allocation method uses a GIS based LUCIS framework that works on the concept of assigning land use based on its suitability for the proposed land use, as described earlier in the literature review section of the research document (Refer Section - Land Use Modeling and Suitability Analysis). The LUCIS method uses a set of goals and objectives, which work as rules and assumptions for allocating the population. It allocated population on the basis of suitability, and involves creating suitability rasters for individual land uses like SF, MF, SER, RET, COM, IND, INST, etc. These suitabilities are determined on the basis of certain criteria's like distance of land use in terms of accessibility from transit, roads, water, land development characteristics like soil, water level, conservation etc. The suitabilities raster converts to preference and conflict rasters, where a preference raster for a land use indicates the areas that are most and least preferred for future development for the individual land use, where as a conflict raster indicates the range of conflict for proposing the land use in a particular area. Based on the analysis of conflict and suitabilities raster, the LUCIS method allocates population and employment to the most suitable land. The LUCIS framework involves creation of all raster datasets required to allocate population in its most suitable land use. The various rasters created in the study and data used for creating them is detailed as a subsequent section in the Chapter 5.

The scenarios also utilize the TOD guidelines as recommended by FDOT in the Florida, for allocating mixed land uses in the TOD buffers. The guidelines provide density and intensity ranges for a distance of half-mile radius from transit stops to allocate future population. The 2035 MVP explains the need of bus transit, with future needs of a commuter rail in the county (2035 MVP, pg 127), therefore uses the T-3 Suburban scenario of light rail, rapid bus transit and commuter rail for medium density TOD calculations. However, another low-density scenario that uses the T-2 suburban scenario, as an alternate is also predicted for the Polk County. The Highlands County in its LRTP proposes a bus system for the region, therefore according to FDOT – TOD guidelines, a T-2 standards for bus system is used a guideline for TOD calculations.(

Appendix F, Figure F-1and Appendix G, Figure G-1 for T2 and T3 standards of TOD development in FDOT Guidelines)

The method of creation of these LUCIS based future scenarios for the two county regions involves some basic steps as described below,

- **Creation of Data set for GIS based LUCIS Framework**- All the suitability rasters for various land uses like SF, MSF, MF, SER, RET, COM, IND, INST, and other GIS datasets in the form of rasters, like TOD buffers, mixed use and redevelopment rasters, etc. is developed for this stage.
- **Identifying Lands For Development** – Using GIS based tools, the land suitable for future growth was determined.
- **Establishing Guidelines for Mixed use and Redevelopment in the Buffers**- The study establishes certain guidelines in the form of density for mixed use development, etc based on the FDOT- TOD guidelines and the assumptions for redevelopment in the study area for the 2035 scenario. The detail of guidelines in the form of tables is available in the subsequent section of the report.
- **Calculating Existing Gross Densities in the Study Area** – These gross densities calculated based on the traffic analysis zone (TAZ) with the existing population and employment totals with study region is helpful in understanding the existing conditions of the study area and future trend.
- **Estimating the Growth Estimate or Control Total for the Study Area** - In order to establish the amount of growth for allocating future population in the scenarios, total number of population and employment were estimated after deducting the projected numbers from the current time.
- **Allocating the Future Land Use** – based on the set of assumptions as described earlier, and using the GIS tool of combine and allocation methodology (as explained later in Chapter 5), the growth was allocated to the counties and summary of total allocation was recorded for analysis.

The next section describes these steps of the methodology in detail with use of various data in creating it. The description also details the technical detail of GIS methods and tools utilized in the particular steps of methodology

Creation of Data Set for GIS Based LUCIS Framework

The scenarios for both counties uses, a proposed transit system with transit stops/activity centers on the transit routes being identified for both counties respectively because of long-range transportation plan documents. The Polk County MVP defines the needs and prioritization of the core corridors for the transit requirements of the area and future population. The study utilizes the same proposed transit needs and corridor for the population allocation scenario, which identifies a express bus system with a possibility of light commuter rail in the future. The Transportation model as obtained from the Shimberg Center for Housing Studies at the University of Florida (UF) for the Heartland 2060 Project from CFRPC shows the proposed location of transit system in the form of express bus route in the Highlands County for 2035. The research study uses the same route while modeling for Highlands County, as the future transit needs.

Creating study buffers and designating TOD areas

The allocations of population for the LUCIS based future scenarios were restricted to the buffer areas around the transit stations. The guidelines for establishing the buffer distances were derived from the center scenario used by the Polk County TPO for the long range plan for 2035 (Appendix F, 2035 MVP), as explained earlier in the overview of methodology. In order to achieve the broader aim of economic vitality and compact development for future allocation, scenarios uses, an additional buffer distance around the proposed transit route for mixed use and redevelopment parcels. The following states the various distance criteria for creation of buffer area;

- TOD Area – Buffer 1: Area of quarter mile (1/4) around the activity center as Walkable distance for the transit stop.
- TOD Area - Buffer 2: A zone of half mile (1/2) mile wide buffer around the transit stops and activity centers,

- Buffer 3: Distance of half miles (1/2) around the transit route for redevelopment allocation (Excluding parcels selected around transit stops for same distance)
- Buffer 4: Distance of three-fourth of a mile (3/4) mile around the center square.
- Buffer 5: Distance of 1 mile square around the center.
- Buffer 6: Distance of 3 miles along the transit corridor as it can be a drivable distance for park and ride facilities and is used for allocating the remaining population for transit-preferred development making it a compact development rather than sprawl. (Refer Appendix B-1 and C-1 for Buffers Areas around the Polk and Highlands County)
- Remaining Area of the County – These are the parcels located outside the 3mile buffer distance in the respective counties.

The buffer rasters used for both counties uses following procedures: Create vector shape files for the parcels in the designated buffer areas like quarter mile, half mile parcels in their increasing order of size and subtract these parcels in one buffer from the previous to get parcels applicable only to the scenario. For example, create vector files of parcels by selecting them with buffers distance of quarter mile, and half mile radius. Now using the erase tool in GIS, subtract the parcels of quarter mile from half mile radius parcels, resulting in parcels lying under the half mile buffers not duplicated by the quarter mile parcels buffer being concentric circles.

Creating suitability rasters and reclassifying

All Suitability rasters or Single Utility Assignments (SUA) for (Urban Suitabilities – Multi Family (MF), Single Family (SF), Commercial (COM), Service, (SER), Retail (RET) Institutional (INS), Industrial (IND) and Agricultural (AG) suitabilities) with the exception of conservation suitability. The suitabilities for each land use like SF, MF are created individually, and are a result of combination of several raster files using a weighted overlay tool in the ArcGIS Spatial Analyst extension. For example, for creating a suitability for SF, buffers are created using buffer tool, based on different criteria's like distance to major roads, close to airport, close to drinking water facilities, around the study area and all individual files are combined using the raster calculator tool in Spatial Analyst with pre assigned weights. These suitabilities for individual land uses like SF, MF, SER, RET, COM, IND, INST, etc are used further to create preference and conflict raster. In general, there is nine categories of suitabilities, in the suitability raster for allocating the future population, which is limited for the analysis as large number of data records is used. In order to allocate future employment and population, the suitability ranges is increased, by using the Slice tool in the ArcGIS, which divides the suitability in to "n" number of classes in to 1000 classes based on equal area for use in the population allocation process.

Creating preference and conflict rasters

In the research study, with exception of conservation suitability, which was provided by Dr. Tom Hoctor from the Geoplan Center, other preference rasters for the urban and agricultural were created using the LUCIS guidelines, goals and objectives. The suitabilities are reclassified into three categories using equal area interval method mainly one (1) – low preference, two (2) - medium preference and three (3) – high preference areas. These preference rasters further make the conflict raster as described below in detail in report

Creating a conflict raster

Conflict surface is a raster depicting areas of conflict within the agricultural, urban and conservation suitabilities for intended development. It is a combination of individual preference rasters with a mathematical equation. A development mask is required to create conflict raster, which acts as a flitter screen for selecting areas of conflict. Following were the steps for creating conflict raster.

A development mask for both counties in the form of raster dataset is developed, using data in the form of raster data with cell size of 31 x 31 and then reclassified with cells depicting conservation or waters areas as No data and others as one (1).
Data sets used for development mask are; Conservation lands for Polk and Highlands, Florida managed lands inventory for the study region, outstanding water bodies for study region.

The development mask uses a Raster Calculator' tool which combines the various raster files in to one file using a mathematical equation and 'Mosaic to New Raster tool' which joins the multiple raster datasets in one single entity raster similar to joining a tile in mosaic. After creation of development mask, the various raster suitabilities created (as described in earlier section) is further converted to preference rasters by reclassifying the values in to three categories of one (1) = low, two (2) = medium and three (3) = high suitability using a standard deviation classification.

These preference rasters are combined using raster calculator tool with input layers as the final agricultural preference, conservation preference raster and urban preference with the following expression, which results in a conflict raster.

" Pref_Ag*1000+ Pref_Cons*10+Pref_Urban" = Conflict Raster

The result is the conflict raster with 27 unique values ranging from 111 to 333 where 111 represents areas in conflict with least development preference, and 333 represents areas of preference with high development preference but all in conflict of development.

Creation of mixed use development raster (MXD)

The mixed-use development raster uses INS (Institutional), MF (Multi-family), and SER (Service), RET (Retail), COM (Commercial) suitabilities as input. The suitabilities changed to preference raster (reclassified using quarter (1/4) std. deviation in to three categories or low, med and high preference), is combined using the raster calculator to form a mixed use development raster

Creating a redevelopment raster:

The redevelopment raster indicates areas that have a potential for redevelopment in the study area, identified on certain criteria's. It is done by querying the vector parcel data to locate areas that met certain criteria and then exporting the file to a raster format. Redevelopment and infill areas suitable for development and growth were selected using select by attributes from the parcel data. Only those parcels that are developable, i.e. free from any conservation, lakes etc. is selected and the criteria's for selection are:

1. Cells within half-mile (1/2) buffer of future transit stations/activity centers or main transit corridors.
2. Parcels with a just value or land value‟ that is below the average
3. Parcels with buildings that will be more than 50 years old in 2035, i.e. were built prior to 1985,and;
4. Exclude parcels with the following uses – churches, orphanages, hospitals, schools, sanitariums, homes for the aged, and cemeteries

These selected cells remain un-duplicated as excluded from the half-mile buffer parcels for allocation purpose

Identifying Lands for Development

Lands available for development is identified as vacant and developable lands within the parcels after removing all sensitive lands like wetlands, open water, military land which can be termed as unfit for future development

Establishing Guidelines for the Allocation Purpose

The mixed use and redevelopment was restricted to half-mile buffer distance from the transit stops, as the literature defines are as the ideal distance for walkability. For promoting mixed-use development for the future scenario, the research study utilizes design guidelines for TOD and allocates redevelopment in selected parcels within half-mile of the transit station. (Refer Section – Creating a redevelopment raster for criteria's). Design guidelines developed by the Florida Department of Transportation (FDOT) for TOD development intends to promote and implement development that is supportive of transit investment. These guidelines provide a framework for variables like, population and employment density, intensity and diversity of land uses, parking availability, and the physical design of the street network to provide connectivity and accessibility, which can be used for development around transit station. These guidelines are effective for its density and intensity ranges for areas located within an approximate half-mile radius of a planned or existing transit station (FDOT, 2009, pg. 1).

The 2035 MVP explains the need of bus transit, with future needs of a commuter rail in the county (2035 MVP, pg 127), therefore for TOD calculations, the T-3 suburban scenario of light rail, rapid bus transit and commuter rail is used. However, the transport model and LRTP of the Highlands County indicates a proposed bus system for the 2035 scenario, thus for TOD calculations, T-2 suburban scenario of bus transit is used. Appendix B-1 and B-2 for Polk County and Appendix C for Highlands County shows the proposed planned transit bus route with proposed transit stops and buffers. Appendix F-1 and F-2 shows the T2 and T3 standards in FDOT Guidelines. The mixed-use densities in the form of residential and employment categories are determined for distributing the population in these redevelopment and TOD areas. The scenario uses an assumption that the employment in the form of commercial and service shall be promoted in the TOD area and a ratio of 30:60 is assumed while allocating population for employment purpose in mixed-use development.

Table 5-1. Development guidelines for low-density scenario – Polk County

Estimated Number of People to allocate from 2007 - 2035			484575
Population to allocate in TOD (Buffer, 1,2) - Redevelopment @ MU Density			55,318
Population to be compacted in half-mile buffer of transit route - MF Development 20% of total population)			85,851
Total in Buffers 1-3			141,169
Number to Vacant Res. and Greenfield (Remaining)			343,406
Total to allocate			484,575
	Existing in 2007 (%)	Target for 2035 (%)	Population to Allocate in 2035 (Number of People)
Percentage of Population inside Buffers	41	80	387,660
Remaining Population outside Buffers	59	20	96,915
Total Allocated			484,575
GROWTH ALLOCATION ASSUMPTION GUIDELINES FOR BUFFERS			
Single Family Growth in 2035			
Assuming that 50% of the total growth (2035) will be in SF			242287.5
Out of which, 85% will be in buffer areas (1-5)			205944.375
Remaining 15% will be outside buffer areas			36343.125
Multifamily Growth in 2035 (including the Mobile homes)			
40% of total growth to be compacted in MF			193830
Assuming that 90% is inside buffers			174447
TOD area (buffer 1 and 2) @MU Density			55,318
Buffer 3 - 1/2 mile buffer for transit stops			85,851
Buffer 4 - .75			3,100
Buffer 5 - 1 mile			8,200
Buffer 6 - 3 miles			22,000
Outside Buffers			19,383
Total Allocation to be done			193,852
Mobile Homes Growth in 2035 - 10% of the total Population			
All outside Buffer Area			48457.5
TOTAL ALLOCATION			380391.375

Source: Courtesy of Author

Table 5-2. Development guidelines for medium-high density scenario – Polk County

Estimated Number of People to allocate from 2007 - 2035			484575
Population to allocate in TOD (Buffer, 1,2) - Redevelopment @ MU Density			85,205
Population to be compacted in half- mile buffer of transit route - MF Development 20% of total population)			79,874
Total in Buffers 1-3			165,079
Number to Vacant Res. and Greenfield (Remaining)			319,496
Total to allocate			484575
	Existing in 2007 (%)	Target for 2035 (%)	Population to Allocate in 2035 (Number of People)
Percentage of Population inside Buffers	41	80	387,660
Remaining Population outside Buffers	59	20	96,915
Total Allocated			484,575
GROWTH ALLOCATION ASSUMPTION GUIDELINES FOR BUFFERS			
Single Family Growth in 2035			
Assuming that 40% of the total growth (2035) will be in SF			193,830
Out of which, 85% will be in buffer areas (1-5)			164755.5
Remaining 15% will be outside buffer areas			29074.5
Multifamily Growth in 2035 (Excluding the Mobile homes)			
50% of total growth to be compacted in MF			242,288
Assuming that 90% of development is inside buffers			218058.75
TOD area (buffer 1 and 2) @MU Density			85,205
Buffer 3 - 1/2 mile buffer for transit stops			79,874
Buffer 4 – 3/4th mile			5,298
Buffer 5 - 1 mile			10,596
Buffer 6 - 3 miles			37,086
Outside Buffers			24228.75
Total Allocation to be done			242,288
Mobile Homes Growth in 2035 - 10% of the total Population			
Outside Buffer Area			48,458
TOTAL ALLOCATION			484,575

Source: Courtesy of Author

Table 5-3. Development guidelines for low-density scenario – Highlands County

Estimated Number of People to allocate from 2007 - 2035		68188.5
Assuming that the 30% of total growth shall be towards the Redevelopment and Mixed use		
Population to allocate in TOD (Buffer, 1,2) - Redevelopment @ MU Density		34,590
Population to be compacted in 1/2 mile buffer of transit route - MF Development 10% of total population)		3,360
Total in Buffers 1-3 (50% of Total Growth)		37949.85
Number to Vacant Res. and Greenfield (Remaining)		30238.65
Total to allocate		68188.5
Total Population of Highlands County - 2010 Census = 100207		
	Existing in 2007 (%)	Target for 2035 (%)
Percentage of Population inside Buffers	81	85
Remaining Population outside Buffers	19	15
Total Allocated		
GROWTH ALLOCATION ASSUMPTION GUIDELINES FOR BUFFERS		
Single Family Growth in 2035		
Assuming that 40% of the total growth (2035) will be in SF		27,275
70% inside the buffers		19,093
30% outside		8,183
Multifamily Growth in 2035 (excluding the Mobile homes)		
50% of total growth to be compacted in MF		40,913
Assuming that it is 90% inside buffers		36,822
TOD area (buffer 1 and 2) @MU Density		34,590
Buffer 3 - 1/4 mile buffer for transit stops		3,360
Buffer 4 - .75		450
Buffer 5 - 1 mile		1,230
Buffer 6 - 3 miles and		1,283
Remaining areas outside the 3 mile buffer		4,091
Mobile Homes - 10% of Growth		
Outside buffer		6,819
Total Allocation to be done		45,004

Source: Courtesy of Author

Table 5-1, Table 5-2 and Table 5-3 provides a detailed calculation of guidelines for low and Med. High Density calculations for the Polk and Highlands County respectively.

The scenario for Polk County uses two density ranges in the form of low and medium TOD density to allocate the growth and compare the extent of proposed compact development. The scenario for Highlands County uses a single scenario of low

TOD density as obtained by using the FDOT- TOD guidelines. The Tables 6-6, 6-7 and 6-8 in the results Chapter 6 shows the detailed density calculations used in allocating the mixed uses for both the counties

Calculating Existing Gross Densities in the Study Area

Calculating the existing gross density will provide an understanding of existing conditions within the study area for residential, commercial, service, and industrial uses. Data in the form of TAZ (2007 data for baseline scenario and 2035 TAZ projections adopted from the transportation models of respective counties) and 2010 parcel data provides base for calculation the existing densities of each land use based on TAZ zone. In order to compare the parcel and TAZ data which uses different land use classification system, the parcel data which contains a land use code used by the Florida Department of Revenue (FDOR) in a range 99 different uses is aggregated to reflect the five different land use categories; single family residential, multi-family residential, commercial, service, and industrial uses. Appendix D lists the FDOR codes aggregated to reflect TAZ land use codes.

The gross density calculation uses two data sets from different sources and is then averaged to get a closest match. For calculating the gross density of population, besides TAZ data, census data was also used. Data from Census Bureau estimates of population and dwelling units by type of residence (five year estimate (2006-2010) for both Polk and Highlands County) is used and summarized according to their residential TAZ land use code; single family, multi-family or mobile home. The data was retrieved from American Community Survey website (ACS) (http://www.census.gov/acs/www/). The Census data was aggregated to match with TAZ land use categories of residential categories (Appendix F lists the aggregation of Census Data to TAZ Land use Categories)

In order to calculate the gross employment densities and achieving a closest match to TAZ data, another data set obtained from American Community Survey website (ACS) based on industry by class category for 5 year estimate for the year 2006- 2010 was used. The data was aggregated using the TAZ land use categories and summarized to calculate the gross employment densities. Appendix E shows the list of ACS data aggregated to the TAZ employment categories

Table 5-4. Total acreage by TAZ land use categories

TAZ LAND USE CATEGORY	POLK COUNTY AREA (ACRES)	HIGHLAND COUNTY AREA (ACRES)
Single Family Residential (SF)	74478.21	16357.67
Multi-Family Residential (MF)	33483.64	4486.72
Service (SER)	38357.41	129222.20
Industrial (IND)	547590.626	442735.30
Commercial (COM)	12583.67	2432.24
Vacant Residential (VAC. RES)	30725.26	22213.17
Vacant Commercial (VAC. COM)	181685.93	6414.50
Vacant Industrial (VAC. IND)	10093.90	284.23
Vacant (VAC)	125121.80	13852.24
No Use Area	201464.63	49977.13
Total Area	1255585.101	687975.4

Source: Parcel data for Highlands and Polk County for the year 2010, Retrieved from www.fgdl.org)

Using the spatial join command in the Analysis tools, developable parcel data is connected to TAZ data to obtain the parcels inside the TAZ. The total number of acres within each of the TAZ land use categories is then calculated by summing the area of the individual parcels within each category. Table 5-4 shows the total acreage in the study area by TAZ land use categories.

Gross Density in each land use is a result of total population or employment in each land use / total acreage of the same land use. (Refer Chapter 6 – Results for Tables 6-1 to 6-8) for existing gross residential and employment densities for both Highlands and Polk County.

Establishing the Control Totals for Growth

In order to establish the amount of growth for allocating future population in the scenarios, estimates of 2006 for Highlands County and 2007 estimates from Polk County population and employment are deducted from forecasts for 2035. Refer Table 6-4 and Table 6-5 for the total growth estimates of Polk and Highlands County. The Table 6-6 lists the employment projections for the 2035 scenario for accommodating in the future scenario.

The next section details the allocation methodology used in the study to allocate future population and employment in the study area. First, the section provides a general understanding of the steps used in allocation with the order followed for allocating population in all buffers of the study are, followed by detailed criteria's for designating special areas, like mixed use development and redevelopment areas in the TOD buffers.

Allocation Methodology

The allocation of projected population and employment through 2035 for both Polk and Highlands County for the alternative development scenario uses the following basic steps within GIS:

- Creation of a Combine raster for each county i.e. Polk and Highlands with all variables used to select land for allocation such as sliced suitability rasters, conflict rasters, and TAZ raster for each buffer. This creates a separate record, with spatial reference, for every possible combination of data included in the Combine. Each combine raster is created using a similar approach with inputs except the buffer distance for each of the combine rasters, as it sets the extent for the combine raster. Appendix H provides a detailed list of combine rasters and its inputs).

- Use a selection query to select records in the Combine attribute table as desired (i.e. placing commercial uses into urban preferred areas with high commercial suitability).
- Multiply the acreage of the selected records by the gross density for the land use associated with each record to determine total population able to be allocated by the current selection.
- Continue making selections until desired population allocation (or acreage) is reached.
- Assign the land use to a new field within the Combine.

For example, while making a combine raster for buffer 1, which is also the TOD and redevelopment area, the redevelopment raster was combined with other rasters like land use suitabilities (MF, SF, COM, SER, IND, INS, RET). The land use suitabilities are sliced suitabilities, i.e. with increased range of suitability from nine to thousand units using the Slice tool in GIS. These suitabilities are combined using the Combine tool in GIS, along with others for final allocation including,

- Conflict surface
- Sliced Multi –family suitability
- Sliced Single Family Suitability
- Sliced Commercial Suitability
- Sliced Industrial Suitability
- Sliced Service Suitability
- Sliced Retail Suitability
- Sliced Institutional Suitability
- Redevelopment Raster
- Mixed use Development Raster
- Buffer 1 raster
- TAZ land use for future

Order of Allocation

In both counties, the LUCIS based future scenario for growth allocation uses and order similar to the buffers around the activity centers in TOD Area. Starting with buffers one and two (i.e. quarter mile and half-mile area buffer around the activity center), the population is allocated in concentric circles in the form of buffers around the transit stations in order to allocate population closest to existing development. As explained earlier in the section (Refer Section - Creating study buffers and designating TOD areas), the buffers are differentiated with each other with respect to the distance form the transit stops. The next allocation is at buffer three, four, and five (half-mile distance around transit station, three-fourth mile and 1-mile distance around the activity center). Finally, population is assigned to buffer six, followed by buffer seven that includes 3-mile buffer and the remainder of the study area in each county.

General Selection Criteria for Allocation into Buffers 1 to 6 for LUCIS Based Future Scenario

In general, the overall methodology for allocating the land parcels for future development remains the same with the use of combine rasters for each buffer. These combine rasters represents combination of different rasters like suitabilities, conflict, future land uses, buffer area rasters etc, in one single raster format. From the attribute table of the each combine raster, for each of the buffers in order as described earlier, cells based on selection criteria's like suitable land use with no or least conflict, is selected. The selected cells acquire a new value with use of field calculator for the population or employment field by multiplying the count of cells by the appropriate gross density. The new value uses a new land use code which is listed in the form of Table 4-5

The guidelines established (as described earlier) for allocating population in all the buffers with total growth estimates guides the process. However, adjustments in order to reach the ultimate goals of compact and integrated development within the buffer zone to promote conservation of natural areas is also done

Table 5-5. Assigned land uses for the allocated population

Existing Land Use Category	Assigned Land Use (NEW_LU)		Existing Land Use Category	Assigned Land Use (NEW_LU)	
Single family	SF	1	Vac. Commercial	VACCOM	7
Multi-family	MF	2	Vac. Residential	VACRES	8
Industrial	IND	3	Agriculture	AG	9
Commercial	COM	4	Conservation	CON	10
Service	SER	5	Ag Preservation	AGPR	11
Vac. Industrial	VACIND	6	Mixed Use	MU	14
Mobile Homes	15		Vacant	VAC	12

Source: Courtesy of Author

Allocation to mixed development opportunity for TOD areas[1]

The raster representing the opportunities for mixed-use development was created in a separate model, as explained earlier in the Chapter 5 (Refer section – Creating mixed use development rasters) in the mixed-use opportunities raster contains a 5-digit value that represents the level of conflict or opportunity that exists between the different land uses in that cells location. For example, a cell in the MXD conflict surface with a value of 33333 represents a good opportunity for mixed use as all of the land uses are highly preferred in that location, and a cell with an 11111 value has few mixed-use opportunities.

The extraction tool in GIS obtains the location of mixed-use opportunities within the buffer 1 and buffer 2. The process of cell selection aims to obtain the cells with high opportunity for mixed-use with a high preference (3) for multi-family combined with a medium (2) or high (3) preference is limited. The size of the selected cells for allocation

[1] This part of the methodology for assigning mixed use land uses only, is inspired by Elizabeth Thompson's Master's Research with University of Florida, where she has allocated mixed land uses in an alternate scenario for a similar kind of research study.

is also limited to more than 1 acre by using the Region Group tool in ArcGIS. Using the Reclassify tool, cells are changed from No Data to zero so that all data is retained during the subsequent combine process of the model. (Thompson, 2010)

The approaching section describes in detail the process of assigning a mixed-use development or redevelopment for both counties as both counties use different densities and assumptions for transit options with an example.

Example of allocating mixed use and redevelopment for TOD areas: The control total i.e. the total amount of population and employment growth for allocation in 2035 for individual counties (Refer Section – Calculating the control total), is the baseline figure for allocation procedure. The allocation is initiated in buffers 1, 2 and 3 that contain all the redevelopment and mixed use parcels in half-mile, half-mile distance in and around the transit stops and route. Since the buffers are also suitable for TOD and redevelopment areas, all population and employment growth is first to be allocated into suitable locations for mixed use redevelopment and then into vacant land uses like vacant residential(VACRES), vacant commercial (VACCOM,) vacant institutional (VACINST), and vacant (VAC).

Based on the TOD guidelines, for allocating population in proposed mixed-use development, the residential component pertains to the MF category and the employment category as COM and SER in a relative proportion of 30: 70. The ratio indicates that 30% of all non-industrial employment growth is COM and 70% is SER. The assumed percentage aims to create a development pattern to promote economic development in the county.

In the attribute table of the TOD combine raster, a selection by attribute is performed to firstly locate cells within redevelopment areas .All cells were assigned a new land use of 14 and population to MF, COM and SER is allocated using the mixed use density which was calculated previously. Once allocated, a summary of total population and acres is recorded for the next group of selection. Now mixed-use parcel , previously identified based on the high and medium mixed-use opportunities, cells are selected which are under the quarter mile and half-mile buffer area and population is allocated to MF, COM, and SER using the mixed-use density with a new land use code. Next, select the remaining parcels in the half-mile buffer for VAC, VACRES, and VACCOM areas, these cells have not been already allocated in the previous step and then selecting all cells that have vacant uses. For the selected cells, using the field calculator tool, population and employment at the mixed-use densities is assigned into the appropriate fields. The scope to increase the residential and employment densities, which is limited to the half- mile buffer area, was determined using the redevelopment parcels and remaining unallocated parcels. The record of remaining area of allocations and count of cells is maintained for further selection.

Finally, the attribute table of the combine raster is summarized and the new population and employment totals are summarized in comparison to the number of estimated population in control totals spreadsheet to determine the remaining growth to be allocated.

Proceeding the allocation process to next buffer level

Allocation of growth to the remaining buffers continues in a similar way. Opportunities for mixed-use redevelopment and redevelopment exist in buffers 1, 2 and 3 and are allocated first in those buffers, followed by vacant land uses based on their level of land use conflict, followed by the suitability for individual land uses. The basis of selection for remaining areas is land use conflict and land use suitability. The method of allocation is the same for both counties, with difference in their level of compactness and calculation of mixed-use densities as different standards for TOD development are used for population allocation. Appendix I shows the complete steps and criteria’s for selection in the form of table for each county used for allocation in all buffers.

CHAPTER 6
RESULTS AND ANALYSIS

Overview

Based on the methodology discussed in Chapter 5, these parts of Chapter 6 provide a detailed calculation results obtained by following the systematic methodology. The chapters details the results achieved in the form of gross density calculations, establishment of the growth or control total for distributing the future population, calculation of mixed use densities used in the TOD areas for compacting the future development patterns, with a summary of population allocation in all the buffers of the respective counties. The Chapter 6 also details an analysis of these results obtained in the form of indicators, assessing the ultimate aim of the research study and provide a background for discussions,

Gross Densities in the Study Area

Tables 6-1 and 6-2 provide gross densities for calculating residential population for Polk and Highlands County, calculated as described in the Chapter 5. These densities represent the existing conditions of population and employment in the study area and are used for calculating the population that can be accommodated in the vacant land for future land uses after determining its suitabilities under the LUCIS framework, predicting the future scenario. The gross density was calculated using the total acreage of the county and future population data derived from the TAZ land uses categories, available through the transportation travel demand models for each county respectively and census estimates from the ACS (Refer section – Calculating gross density for calculation method and data details). An average of both the total gross densities obtained from Census and TAZ data is taken to allocate residential population to predict the closest match for future. The average gross density as calculated is used to allocate population for the selected areas suitable for residential location.

Table 6-1. Gross residential density – Polk County

LAND USE CATEGORY	TAZ Population Estimate for 2035	Census Population Estimates for 2035	ACRES	TAZ Gross Density	Census Gross Density	Avg. Gross Density
SINGLE FAMILY	458,589	393,339	74478.22	6.15	5.28	5.71
MULTI-FAMILY	113,459	183,626	33483.64	3.38	5.48	4.43
TOTAL	572048	576965	107961.9	5.29	5.34	5.31

Source: Courtesy of Author

Table 6-2. Gross residential density – Highlands County

LAND USE CATEGORY	TAZ Population Estimate for 2035	Census Population Estimates for 2035	ACRES	TAZ Gross Density	Census Gross Density	Avg. Gross Density
SINGLE FAMILY	67,600	69449	16357.67	4.13	4.24	4.18
MULTI-FAMILY	45, 367	28245	4486.72	10.11	6.29	8.2
TOTAL	112, 967	97694	20844.39	5.41	4.68	5.05

Source: Courtesy of Author

Growth Estimate/ Control Totals for Final Allocation

The growth estimate or control total refers to the total number of population and employment growth predicted for the long-range plan period. The study uses a period for 2035, which is also the long-range plan period for both Polk and Highlands County. The population projection for both counties as developed by BEBR provides the total population predicted in 2035, which includes the present population. The TAZ data from the transportation models in addition to the future population estimate also provides a prediction of employment population for the year 2035. Therefore, in order to establish the amount of growth to be allocated into the future scenarios, estimates of current population (2006 population data for Highlands County and 2007 population data estimates for Polk County) and employment data are deducted from forecasts for 2035.

This control total provides a base estimate for distributing growth in both counties for the year 2035. An average of both forecasted data for population by BEBR and TAZ as used in the transportation models for same horizon year of 2035 is considered, in order to get a closest possible match for the prediction scenario. Table 6-3 and Table 6-4 lists the population growth in terms of control total for Polk and Highlands County, which is the target number to reach, while distributing the population for the scenario of 2035 .estimates and forecasts used and their averages that result in the control totals used for this study.

Table 6-3. Population control total/ growth estimate – Polk County

Population Forecasts by BEBR	Current (2010)	Medium	High	Avg.Med-High
2010	602095	-	-	-
2020		713900	773700	1100750
2035		881700	1067900	1415650
Population Projections/Estimates	Total	Average	Control Total	
2035 population estimates BEBR - (Med-High)	1415650			
2035 population estimates TAZ data	995050			
2035 Population Average		1205350		
2010 Population estimates BEBR	602095			
2006/2007 Population estimate TAZ	839455			
2006/2007 Population Average		720775		
Total Population Growth - 2006 -2035			484,575	

Source: Courtesy of Author

Table 6-4. Population control total/ growth estimate – Highland County

Population Forecasts by BEBR	Current (2010)	Medium	High	Avg. Med-High
2010	100207			
2020		109300	116100	167350
2035		124600	144200	196700
Population Projections/Estimates	Total	Average	Control Total	
2035 population estimates BEBR - (Avg. Med-High)	196700			
2035 population estimates TAZ data	155999			
2035 Population Average		176349.5		
2010 Population estimates BEBR	100207			
2006/2007 Population estimate TAZ	116115			
2006/2007 Population Average		108161		
Total Population Growth - 2006 -2035			68,189	

Source: Courtesy of Author

Similarly, in order to calculate a target number for employment or estimate of employment population for the year 2035 for distribution in the scenario, TAZ employment data is used. The employment growth or control total for employment was resulted after deducting the current employment data obtained by transportation models at TAZ level, for respective counties from the projected employment data for the year 2035 for Polk and Highlands County Transport Models respectively. Table 6-5 provides a detailed calculation steps for obtaining a employment growth estimate for 2035.

Table 6-5. Employment control total/ employment growth

	Polk County		Highlands County	
Employment Population Projections/Estimates	Total	Control Total	Total	Control Total
2035 Employment population estimates TAZ	472775		64134	
2006/2007 Employment Population estimate TAZ	267407		38560	
Total Employment Population Growth - 2006 -2035		205368		25574

Source: Courtesy of Author

Density Calculation for Mixed use Development in TOD areas

Once the population and employment growth is determined, allocation of lands to future land uses requires densities based on which the population allocated for a piece of land is estimated. Besides the gross densities, as described in the Chapter 5, the study also establishes guidelines for mixed-use development and redevelopment in the TOD area. (Refer Section – Establishing development guidelines for allocation)

Table 6-6. Mixed use density calculation for the Polk County – low density scenario

Total TOD Area (Buffer 1 and 2, i.e. 1/2 mile and 1/4 mile)		5977.432	
Total Redevelopment Area (acres) in buffer 1 and 2		2560	
Inside Buffer 1 and 2		Acres	Population
Residential Area (SF + MF + Mobile homes)		781.806	4,456
SER		612.913	386
IND		945.171	595
COM		781.734	492
Jobs/ Employment (total)		2339.818	1,474
FDOT- TOD Standards for T-2 Rural Low Density - 10 people per acre, 2 Jobs per Acre and 2 DU per Acre			
T-2 scenario for Buffer 1 and 2	@2 DU per Acre	@2 Jobs per Acre	10 People per acre
Population estimates for 2035	11,955	11,955	59,774
Mixed use Density calculation in TOD Buffer			
Inside Buffer 1 and 2	Existing Population	Additional Population required for TOD	Acres
Res. (SF+MF+Mob)	4,456	55,318	781.806
Jobs (Com+ Ser+ Ind)	1,474	10,481	2339.818
DU (ResPop/5.74)	782	11,173	776.30
Mixed Use Densities for Low TOD Development			
MU Density for Residential = (Req. Pop/Red. Area) - 29.27			
Mu Density for Jobs (COM- 30% of total jobs) - 1.66			
MU Density for Jobs (SER – 70% of total Jobs) - 3.88			

Source: Courtesy of Author

For Highlands County, the scenario uses the future transit system anticipated by the transportation model in the making of the 2035 LRTP, which proposes a bus route for transit development. The LRTP for Highlands County prepared for 2035 scenario is still in process for adoption, as the county is not required to adopt a LRTP, being not a MPO region (Personnel Communication, March 30th, 2012). As described in the Chapter 5 (Refer Section – Overview of methodology for assumptions), since no information is available for future transit stops in these proposed routes, the transit stops as identified activity centers is assumed on these routes.

Table 6-7. Mixed use density calculation for the Polk County – medium density

Total TOD Area (Buffer 1 and 2, i.e. 1/2 mile and 1/4 mile)		5977.432	
Total Redevelopment Area (acres) in buffer 1 and 2		2560	
Inside Buffer 1 and 2		Acres	Population
Residential Area (SF + MF + Mobile homes)		781.806	4,456
SER		612.913	386
IND		945.171	595
COM		781.734	492
Jobs/ Employment Population		2339.818	1,474
FDOT- TOD Standards for T-2 Rural Low Density - 10 people per acre, 2 Jobs per Acre and 2 DU per Acre			
T-2 scenario for Buffer 1 and 2	@5 DU per Acre	@5 Jobs per Acre	@ 15 People per acre
Population estimates for 2035	29,887	29,887	89,661
Mixed use Density calculation in TOD Buffer			
Inside Buffer 1 and 2	Existing Population	Additional Population required for TOD	Acres
Res (SF+MF+Mob)	4,456	85,205	781.806
Jobs (Com+ Ser+ Ind)	1,474	28,413	2339.818
DU (ResPop/5.74)	782	29,105	776.30
Mixed Use Densities for Low TOD Development			
MU Density for Residential = (Req. Pop/Red. Area)			33.28
Mu Density for Jobs (COM- 30% of total jobs)			3.33
MU Density for Jobs (SER – 70% of total Jobs)			7.77

Source: Courtesy of Author

The mixed use density calculations for Polk and Highlands County uses the T-3 and T-2 suburban scenarios respectively, developed by FDOT to establish guidelines for promoting transit investments. The T-3 and T-2 scenario provides parameters in terms of population and employment density, parking standards, intensity and diversity of land uses for considering the TOD. The T-3 and T-2 scenario for both low and medium density for the Polk County uses a proposed transit system in the form of express bus service and light rail, where as the T-2 scenario for the Highlands County uses the bus system as proposed transit for calculating the mixed-use densities. Table 6-6 and Table 6-7 provide a detailed calculation for mixed-use development in Polk for low and medium density scenarios based on T-2 and T-3 suburban scenarios, whereas Table 6-8 provide mixed-use density calculation for a single scenario of low density development in the Highlands County for distributing MXD in TOD areas.

Table 6-8. Mixed use density calculation for the Highland County

Total TOD Area (Buffer 1 and 2, i.e. 1/2 mile and 1/4 mile)		5579	
Total Redevelopment Area (acres) in buffer 1 and 2		1195	
Inside Buffer 1 and 2		Acres	Population
Residential Area (SF + MF + Mobile homes)		5300	21,200
SER		3931	432
IND		21671	1,950
COM		1140	285
Jobs/ Employment Population		26742	2,668
FDOT- TOD Standards for T-2 Rural Low Density - 10 people per acre, 2 Jobs per Acre and 2 DU per Acre			
T-2 scenario for Buffer 1 and 2	@2 DU per Acre	@2 Jobs per Acre	10 People per acre
Population estimates for 2035	11,158	11,158	55,790
Mixed use Density calculation in TOD Buffer			
Inside Buffer 1 and 2	Existing Population	Additional Population required for TOD	Acres
Res. (SF+MF+Mob)	21,200	34,590	5300
Jobs (Com+ Ser+ Ind)	2,668	8,490	26742
DU (ResPop/5.74)	4,240	6,918	923.4
Mixed Use Densities for Low TOD Development			
MU Density for Residential = (Req. Pop/Red. Area)			28.9
Mu Density for Jobs (COM- 30% of total jobs)			7.1
MU Density for Jobs (SER – 70% of total Jobs)			5.8

Source: Courtesy of Author

Summary of Population Allocation

Based on the above guidelines and criteria, all the buffers in both counties were allocated population growth. The population distribution is restricted in terms of buffers as described earlier in the report and the areas outside the buffers, is termed as the remaining county area. Table 6-9 provides a summary of allocation for LUCIS based future scenario using low-density guidelines for Polk County, whereas the Table 6-10 provides a summary of population allocation for medium density scenario of Polk County.

The comparison of two scenarios for the same county i.e. the low density and medium density scenario for the Polk County indicates that with change in density can play an important role in shaping the development pattern. Based on the assumptions and development guidelines for the scenarios, both the scenarios have achieved the objectives in terms of compact development. The medium density scenario distribution of residential population (SF and MF) is more than the low-density scenario in the buffers. In addition, the allocation of MF is more in the medium density scenario with use of higher densities as established in the guidelines to achieve a more compact and viable development pattern. (Refer Chapter 5, Section- Establishing guidelines for development)

Table 6-9. Summary of population allocation in Polk County – low-density scenario

Buffers	SF	MF	COM	SER	IND	MOB
Buffer 1 -1/4th mile	890	5079	320	2150	0	0
Buffer 2 - 1/2 Mile	3,816	11,363	1,259	5,259	14	0
Buffer 3 -1/2 Mile around Transit route	66,589	56,438	28,989	63,615	111	0
Buffer 4 -3/4th Mile	679	4,523	2,177	5,827	0	0
Buffer 5 - 1 Mile	11,259	5,678	2,516	5,876	19	0
Buffer 6 - 3 Mile	75,890	45,875	13,445	30,610	111	0

Table 6-9. Continued

Buffers	SF	MF	COM	SER	IND	MOB
Remaining County Areas	82,347	64,960	11,320	29,890	1,200	48,457
Total Allocated	241,470	193,916	60,026	143,227	1,455	48,457
Summary – Inside Buffer : Outside Buffer						
Total Allocated Inside Buffer	159,123	128,956	48,706	113,337	255	0
Total Allocated Outside Buffer	82,347	64,960	11,320	29,890	1,200	48,457
Total Allocated	241,470	193,916	60,026	143,227	1,455	48,457

Source: Courtesy of Author

Table 6-10. Summary of population allocation in Polk County – medium density scenario

Buffers	SF	MF	COM	SER	IND	MOB
Buffer 1 -1/4th Mile	586	6780	480	3745	0	
Buffer 2 - 1/2 Mile	2,977	17,834	1,973	5,674	14	
Buffer 3 -1/2 Mile around Transit route	48,103	68,647	29,310	69,879	111	
Buffer 4 -3/4th Mile	679	4,523	2,177	5,827	0	
Buffer 5 - 1 Mile	9,738	5,678	2,516	5,876	19	
Buffer 6 - 3 Mile	82,347	58,734	13,445	30,610	111	48457
Remaining County Areas	49,860	78,925	11,320	24,320	1,200	
Total Allocated	194,290	241,121	61,221	145,931	1,455	48,457
Summary – Inside Buffer : Outside Buffer						
Total Allocated Inside Buffer	144,430	162,196	49,901	121,611	255	0
Total Allocated Outside Buffer	49,860	78,925	11,320	24,320	1,200	48,457
Total Allocated	194,290	241,121	61,221	145,931	1,455	48,457

Source: Courtesy of Author

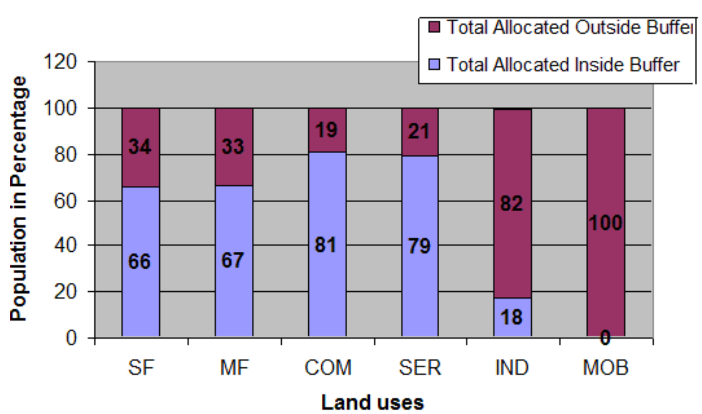


Figure 6-1. Comparison of population distribution - low density scenario, Polk County, chart courtesy of author

Figure 6-1 illustrates the various land uses inside the buffers and outside the buffers for the low-density scenario. The chart indicates that about 66% of the total population allocated in the SF category, lies within the 3-mile buffer distance of the transit station, where as about 67% of the MF population is inside the buffer area.

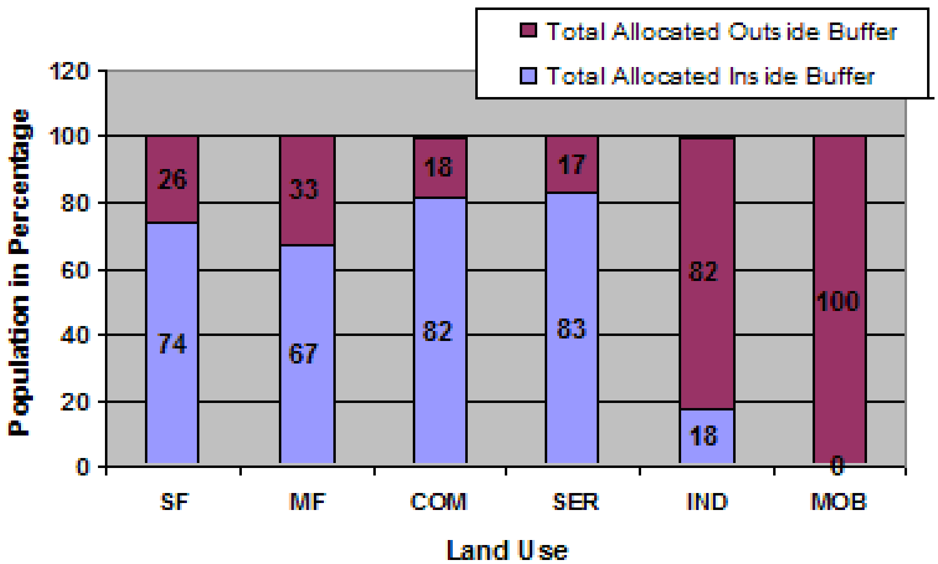


Figure 6-2. Comparison of distribution for medium density scenario, Polk County, chart courtesy of author

Table 6-11. Summary of population allocation in Highlands County

Buffers	SF	MF	COM	SER	IND	MOB
Buffer 1 -1/4th mile	479	1751	250	350	0	0
Buffer 2 - 1/2 Mile	1,117	2,140	490	2,140	125	0
Buffer 3 -1/2 Mile around Transit route	15,432	13,260	1,095	2,278	470	0
Buffer 4 -3/4th Mile	250	2692	1450	4320	90	0
Buffer 5 - 1 Mile	1,020	7680	790	2,500	98	0
Buffer 6 - 3 Mile	1,540	10,150	1,260	3,200	1,780	0
Remaining County Areas	8,081	3,447	4,425	1,736	139	6,819
Total Allocated	27,919	41,120	9,760	16,524	2,702	6,819
Summary – Inside Buffer : Outside Buffer						
Total Allocated Inside Buffer	19,838	35,922	5,085	14,438	2,563	0
Total Allocated Outside Buffer	8,081	3447	4425	1,736	139	6,819
Total Allocated	27,919	39,369	9,510	16,174	2,702	6,819

Source: Courtesy of Author

Table 6-11 lists the distribution of population in designated buffers as discussed in the Chapter 5 for the Highlands County. The table shows that the distribution allocated more population in the MF land use than the SF, indicating a compact development.

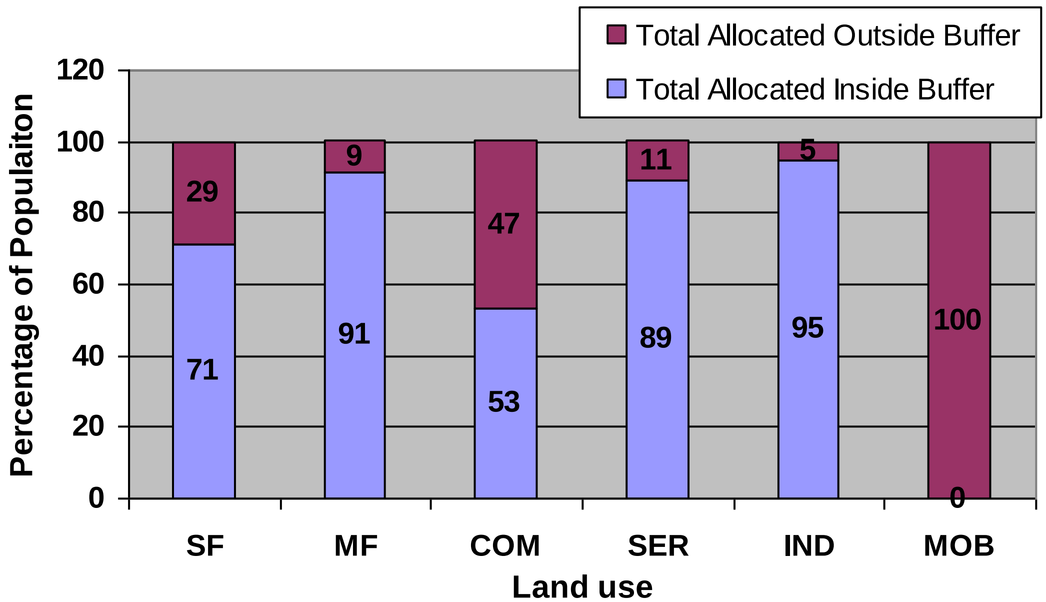


Figure 6-3. Comparison of distribution – Highlands County, chart courtesy of author

Analysis Indicators for Proposed Scenarios

Keeping the smart growth principles in mind, for a growth scenario that completely integrates the land use and transportation decisions for the future generations, this study aims to develop an alternate scenario using GIS-based LUCIS modeling for the making of long-range plans like long range transportation plans. The goals selected for study was based on the goals envisioned by the Heartland 2060 project as well as by the individual long-range transportation plans for Polk and Highlands County, which are also based on principals of smart growth.

The research compares the LUCIS based future scenario with present conditions and methods of forecasting the land use and transportation integration for the long rage planning. The research uses various indicators like extent of urban sprawl, increase in mixed-use development, etc. for analyzing the compactness of the proposed scenarios for the both counties. The research also uses indicators accessibility for new dwelling units, diversity in land uses etc for analyzing the proposed reduction in carbon footprints. The research also assesses the effectiveness of the suitability method for land development by analyzing the usage of agricultural and conservation lands for the scenarios. A comparative analysis for both counties of the proposed suitability based GIS model outputs with the available transportation models and methods used by the both counties respectively for 2035 horizon, portrays a clear picture.

Measuring Compact Development

Compact development promotes and encourages higher density development, mixed-use development, and commercial/residential infill (re)development that uses land more efficiently and provides a range of living choices, employment opportunities, and access to services using transit and active transportation modes. The compactness of the development is analyzed with the extent to which a land use pattern is proposed with respect to the transportation route choices available in terms of population and employment density within particular distances in a region. The proposed LUCIS based future scenario promotes development within a 3-mile distance of proposed transit corridor in both respective counties; as compared to the existing scenario. The following indicators analyze the compactness of the LUCIS based future scenario.

Extent of urban sprawl:

Urban sprawl is associated with two factors mainly, the density of population growth and boundary of urban land, as the sprawl indicates low-density population expansion in city limits. Therefore, in this study, the measure of compactness of the proposed scenario is restricted to an inside and outside of 3-mile distance, which is also the distance of last allocation buffer from the transit stops. The distance of 3-mile from the transit stops is a reasonable distance for drivers to commute to park and ride facilities and promotes a transit-preferred development. buffer distance from the existing scenario based on TAZs.

Table 6-12. Comparative analysis of population and employment distribution in 3-mile buffer distance – Polk County

Within 3 miles of transit route	2007 TAZ	2035 MVP scenario	Low Density Scenario - Total	Medium-High Density Scenario - Total
Single Family	253,704	451,258	412,827	398,134
Multi-Family	60,182	84,491	189,138	232,168
Total Population (Buffers 1 to 3)	313,886	535,750	601,965	630,302
% of Total Population	58	58	61	64
Commercial	31,054	82,771	79,760	80,955
Service	65,615	105,612	178,952	187,226
Industrial	41,592	66,488	41,847	41,847
Total Employment Population (Buffers 1 to 3)	138,260	254,871	300,558	310,027
% of Total Employment	58	57	68	70
Outside 3 miles of transit	2007 TAZ	2035 MVP scenario	Low Density Scenario - Total	Medium-High Density Scenario - Total
Single Family	14096	23475	265,579	233,092
Multi-Family	8029	7529	113,110	117,075
Total Population (Buffers 1 to 3)	22125	31004	378,689	350,167
% of Total Population	42	42	39	36
Commercial	824	1821	32,846	32,846
Service	2297	12192	75,930	70,360
Industrial	2807	7576	31,735	31,735
Total Employment Population (Buffers 1 to 3)	5928	21589	140,512	134,942
% of Total Employment	42	43	32	30

Source: Courtesy of Author

Table 6-12 indicates that the total population allocation in low and medium density scenarios for Polk County is higher than the 2035 MVP scenario. The percentage of population distribution inside and outside the 3-mile buffer zones provides a comparative scenario for both low and medium density with the 2035 MVP scenario.

Since the data for 2035 MVP is TAZ based and provide details of estimate of population allocation at TAZ level, unlike the study, which uses the distance measure of miles from transit station. The table uses some assumptions and aggregations of data in order to create a comparative analysis that is also valid for the Highlands County. In order to obtain, the closest population allocated inside the 3-mile buffer zone in the 2035 MVP scenario, the total population of all the TAZs that intersected with 3-mile buffer is used and aggregated with an assumption that actually only 60% of the TAZ population is inside the buffer and remaining contributes to outside the buffer areas. The percentage of total population indicates the ratio of total population inside the buffer to the 2007 population in the same buffer. The percentage of population for 2035 MVP indicates that the scenario allocates 58% of the total growth inside the 3-mile buffer when aggregated using the TAZ data, however, the low and medium density scenario allocates, 61% and 64% of total population inside the 3-mile buffer. (Refer Table 6-12)

For both, population and employment distribution for 3-mile buffers, the low density and medium density scenario is for the Polk County show higher percentage of concentration of population and employment distribution in comparison to the 2035 MVP scenario. The medium density scenario incorporates 4% more population and 12% more employment inside the 3 mile of proposed transit route than the 2035 MVP, whereas the low-density scenario takes in to account 3% more population and 11%

more employment population inside the 3-mile buffer. Figure 6-4 shows the inside and outside of 3-mile buffer distance for Polk County, with the TAZ extents for the buffers, as the TAZ data reflects the population prediction for 2035 scenario in the MVP. Table 6-12 list the percentage of development within the 3 mile of buffer distance from the existing scenario based on TAZs.

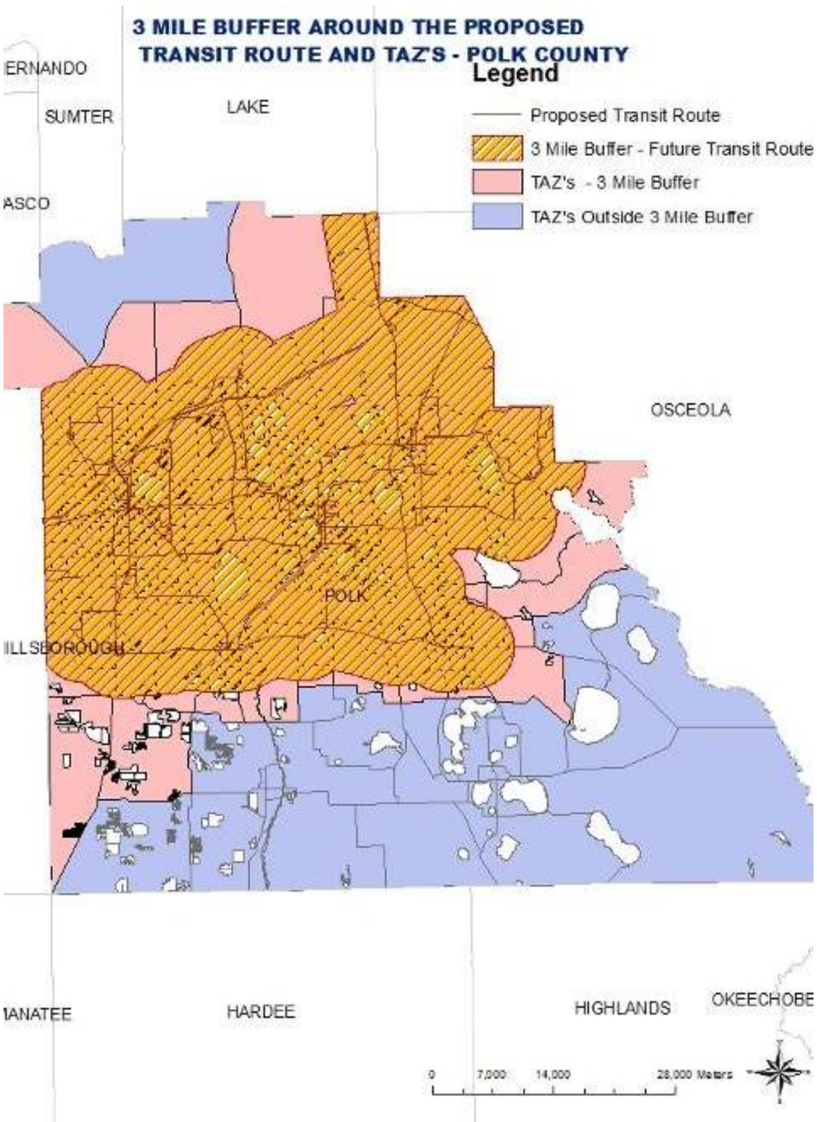


Figure 6-4. Map of 3 mile buffer around the transit route in Polk County, Map source: courtesy of author

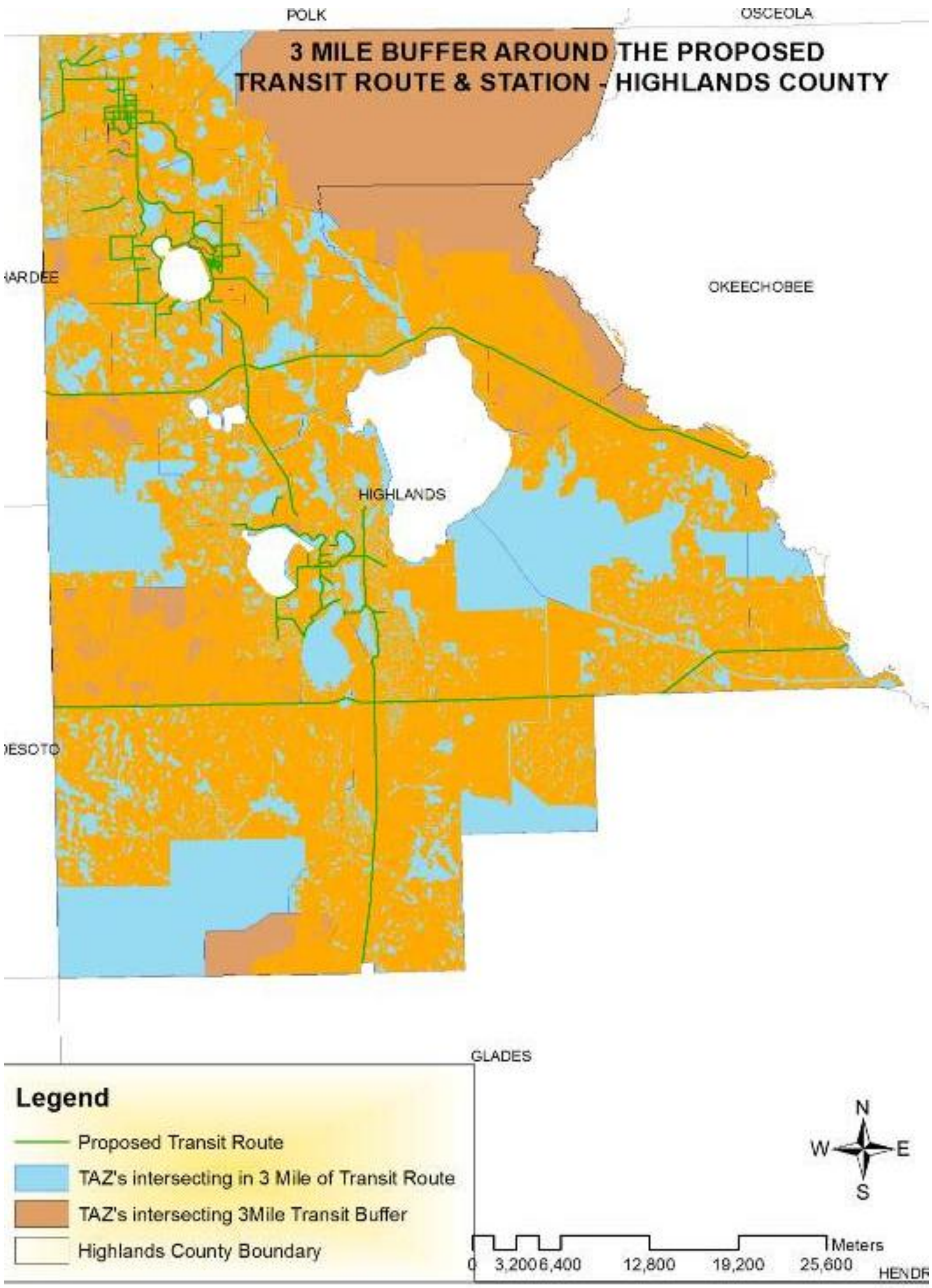


Figure 6-5. Map of 3-mile buffer around the transit route in Highlands County, Map courtesy of Author

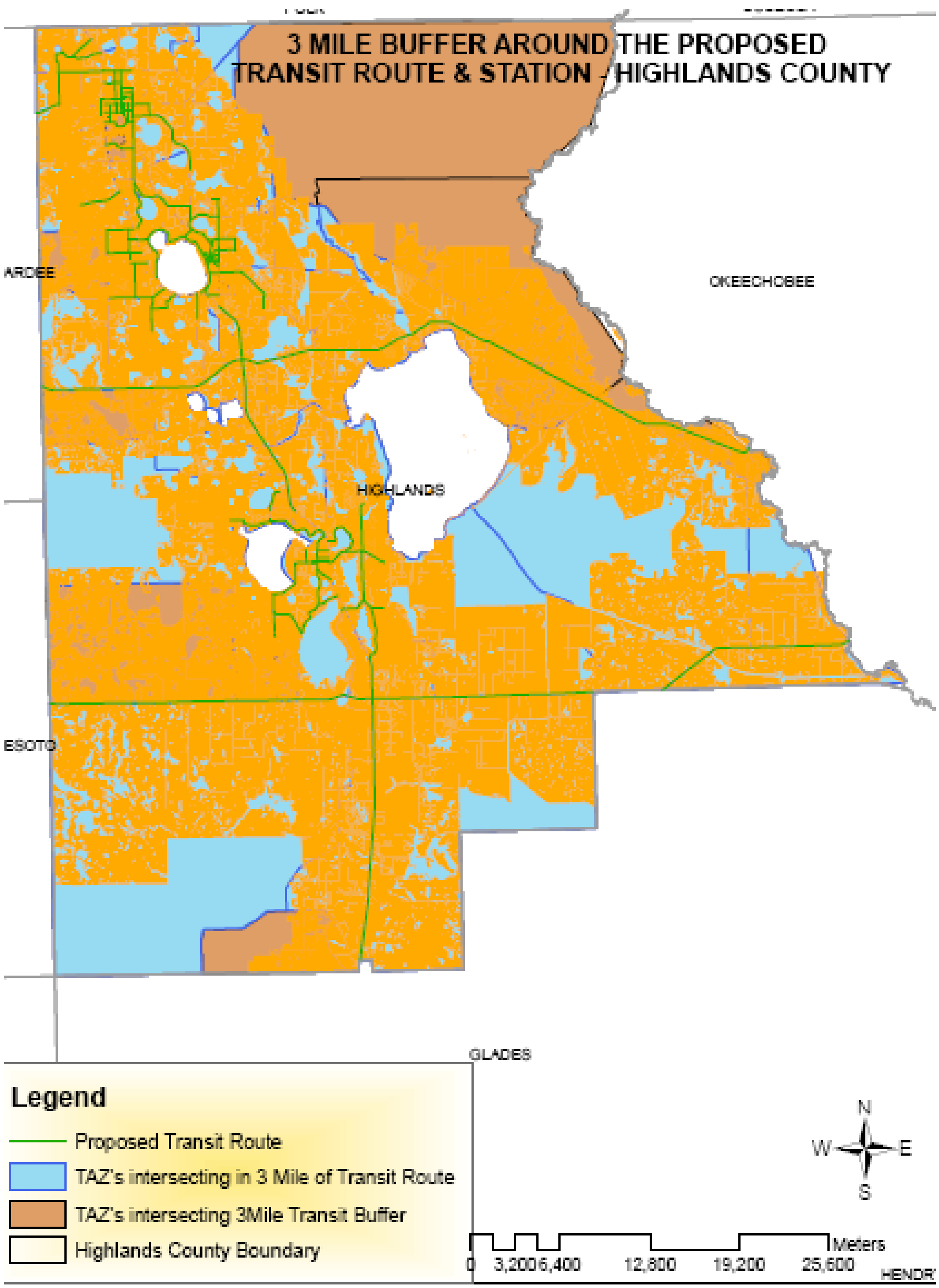


Figure 6-6. Map of half- mile buffer around the transit route in Highlands County, Map Courtesy of Author

Table 6-13 list the percentage of development within the 3 mile of buffer distance from the existing scenario based on TAZs for Highlands County. Incase of Highlands

County, the alternate low-density scenario allocates 80% of the total population inside the 3-mile buffer distance from the transit route, making it more compact and denser than the 2035 LRTP scenario, as the scenario predicts 61% of total population inside the 3-mile buffer. It also incorporates 10% of more employment population than the LRTP scenario.

Table 6-13. Comparative analysis of population and employment distribution in 3-mile buffer distance – Highlands County

Within 3 mile of transit	2006 TAZ	2035 Highlands LRTP scenario	Alternate Growth Scenario
Single Family	36,334	56,974	56,172
Multi-Family	26,388	37,374	64,061
Total Population (Buffers 1 to 6)	62,722	94,349	120,233
% of Total Population	77	61	80
Commercial	5,318	10,503	11,982
Service	8,498	18,626	25,411
Industrial	2,438	4,656	5,611
Total Employment Population (Buffers 1 to 6)	16,254	33,786	43,004
% of Total Employment	89	69	79
Outside 3 mile of transit	2006 TAZ	2035 Highlands LRTP scenario	
Single Family	11,177	46,998	19,258
Multi-Family	8,062	13,039	11,509
Remaining County Population	19,239	60,036	30,767
% of Total Population	23	39	20
Commercial	1,582	4,423	6,007
Service	2,340	7,881	4,076
Industrial	870	2,540	1,009
Remaining County Employment	4,792	14,843	11,092
% of Total Employment	26	31	21

Source: Courtesy of Author

Proximity of dwelling units to transit stops or routes (1/2 mile distance from stop or transit stop)

Distance of housing and employment from transit stations is a strong measure of evaluating the effectiveness of TOD in reducing VMT. The specific performance indicators are percentages of housing units and total employment within half-mile of transit stations and route, as it indicates the concentration around the transit. In order to analyze the effectiveness of TOD, an indicator in the form of proximity to dwelling units and employment centers for a distance of half-mile from the transit stop and route is used. The percentage indicates the ratio of population allocated within the buffer distance for the future scenario. In order to get a comparative numbers for the TAZ level data of 2035 LRTP for both counties, as the transportation model forecasts population distribution at the TAZ level, while the scenario predicts the population at buffer distances, some assumptions and aggregations of data at TAZ level is required. The population inside the half-mile buffers for the 2035 LRTP was aggregated as 70% of the total TAZ population of the buffers that intersect the half-mile buffer distance, as explained earlier in the section.

Table 6-14 compares the low and medium density scenario predicted using the suitability analysis based on the location of land use near to proposed transit route in Polk County. This analysis provides an overview of the effectiveness of the TOD within the half-mile distance from the transit stops and route. The percentage of population inside the half-mile buffer for both scenarios, show higher concentration of population and employment within the buffer distance when compared to the 2035 MVP scenario for Polk County.

Table 6-14. Comparative analysis of population and employment distribution in half-mile buffer distance – Polk County

Within 1/2 miles of transit route	2007 TAZ	2035 MVP scenario	Low Density Scenario - Total	Medium-High Density Scenario - Total
Single Family	382,829	408,788	339,275	319,646
Multi-Family	95,905	80,887	140,014	170,185
Total Population (Buffers 1 to 3)	478,734	489,674	479,289	489,831
% of Total Population	88	53	55	60
Commercial	33,866	79,147	54,274	65,629
Service	37,101	100,376	96,995	105,269
Industrial	20,480	61,907	14,461	14,461
Total Employment Population (Buffers 1 to 3)	91,535	241,430	165,730	185,359
% of Total Employment	82	56	58	60
Outside 1/2 miles of transit	2007 TAZ	2035 MVP scenario		
Single Family	54,107	366,784	196,731	224,282
Multi-Family	12,427	67,461	198,744	181,920
Total Population (Buffers 1 to 3)	66,534	434,246	395,475	406,202
% of Total Population	12	47	44	40
Commercial	3226	60,626	32684	32684
Service	9192	78,574	75825	81395
Industrial	8357	53,178	9687	9687
Total Employment Population (Buffers 1 to 3)	20,775	192,378	118,196	123,766
% of Total Employment	18	44	42	40

Source: Courtesy of Author

The low-density scenario has 60% of both the study area population and employment located within a half-mile distance of future transit routes, where as the medium density scenario also reflects almost the same trend with 55% population and 58% of employment inside the buffer. The low-density scenario for the Polk County has 5% less more population than 2035 MVP, where as the medium density scenario has 7 % more population than the 2035 MVP. In case of percentage difference in allocation of employment for both low density and high density scenario when compared with 2035 MVP is 2% more for low density and 4% more for medium density. Figure 6-7 shows the areas inside the half-mile buffer from transit stops and transit route for the Polk County.

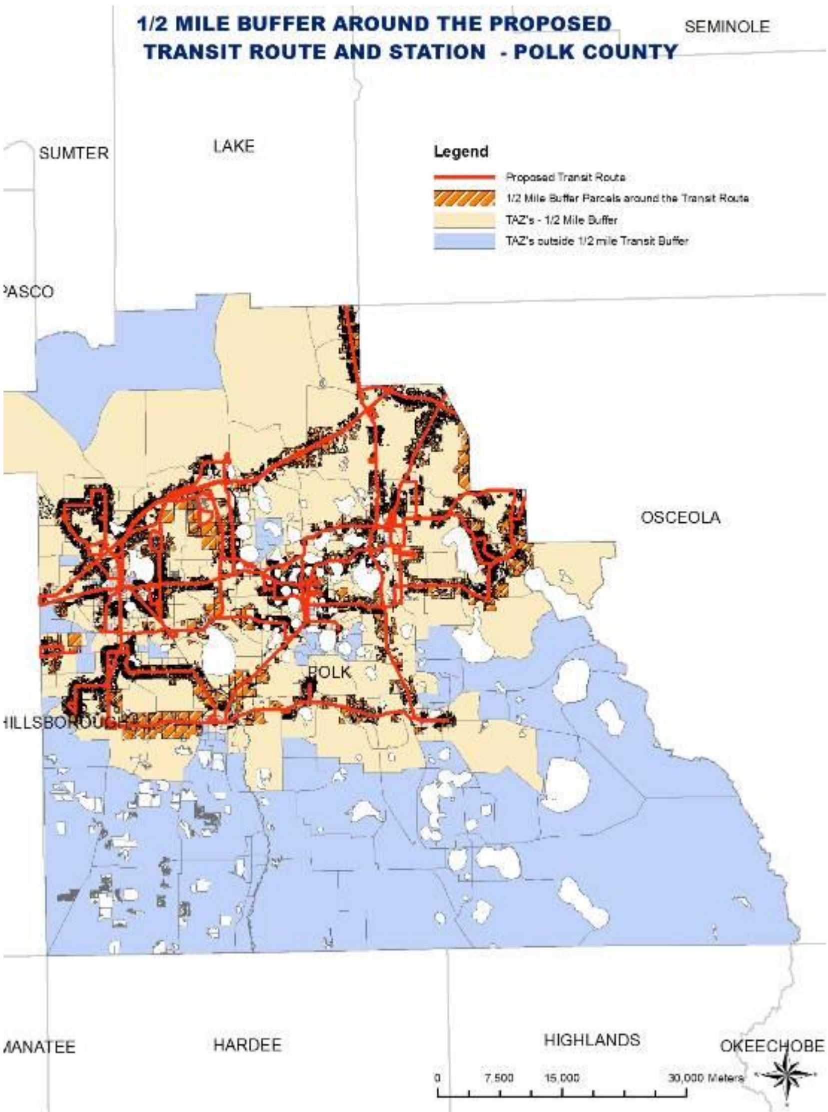


Figure 6-7. Map of half-mile buffer around the transit route in Polk County, Map Courtesy of Author

Table 6-15 indicates the concentration of population and employment within a distance of half-mile from proposed transit routes for Highlands County. When compared at the half-mile buffer distance from the transit stops and transit station, the future scenario for Highlands County, which uses the location of land use near to proposed transit route, shows a more effective TOD development with a compact land use pattern that allocates 76% of the compared to the one proposed in the transport model

Table 6-15. Comparative analysis of population and employment distribution in half-mile buffer distance – Highlands County

Within half-mile (1/2)of transit	2006 TAZ	2035 Highlands LRTP scenario	Alternate Growth Scenario
Single Family	55,637	65,329	72,665
Multi-Family	40,809	36,905	57,960
Total Population (Buffers 1 to 6)	96,446	102,234	130,625
% of Total Population	95	64	76
Commercial	9,564	11,113	11,399
Service	15,264	19,619	20,032
Industrial	4,596	5,503	5,191
Total Employment Population (Buffers 1 to 6)	29,424	36,236	36,622
% of Total Employment	76	63	64
Outside 1/2 mile of transit	2006 TAZ	70%	
Single Family	3,208	41,934	14,099
Multi-Family	1,908	19,532	25,877
Remaining County Population	5,116	61,465	39,976
% of Total Population	5	36	23
Commercial	367	5,840	9,552
Service	498	10,547	15,454
Industrial	236	3,131	4,123
Remaining County Employment	1,101	19,519	29,129
% of Total Employment	23	33.96700543	36

Source: Courtesy of Author

The LUCIS based future scenario has 76**%** of the study area population and 64 % of employment located within a half-mile distance of future transit routes. The LUCIS based future scenario has 12% more population than transportation model scenario, and it also has 1% more employment population then predicted in the model used for long-range transportation plan. Figure 6-8 shows the areas inside and outside the half-mile buffer for the Highlands County.

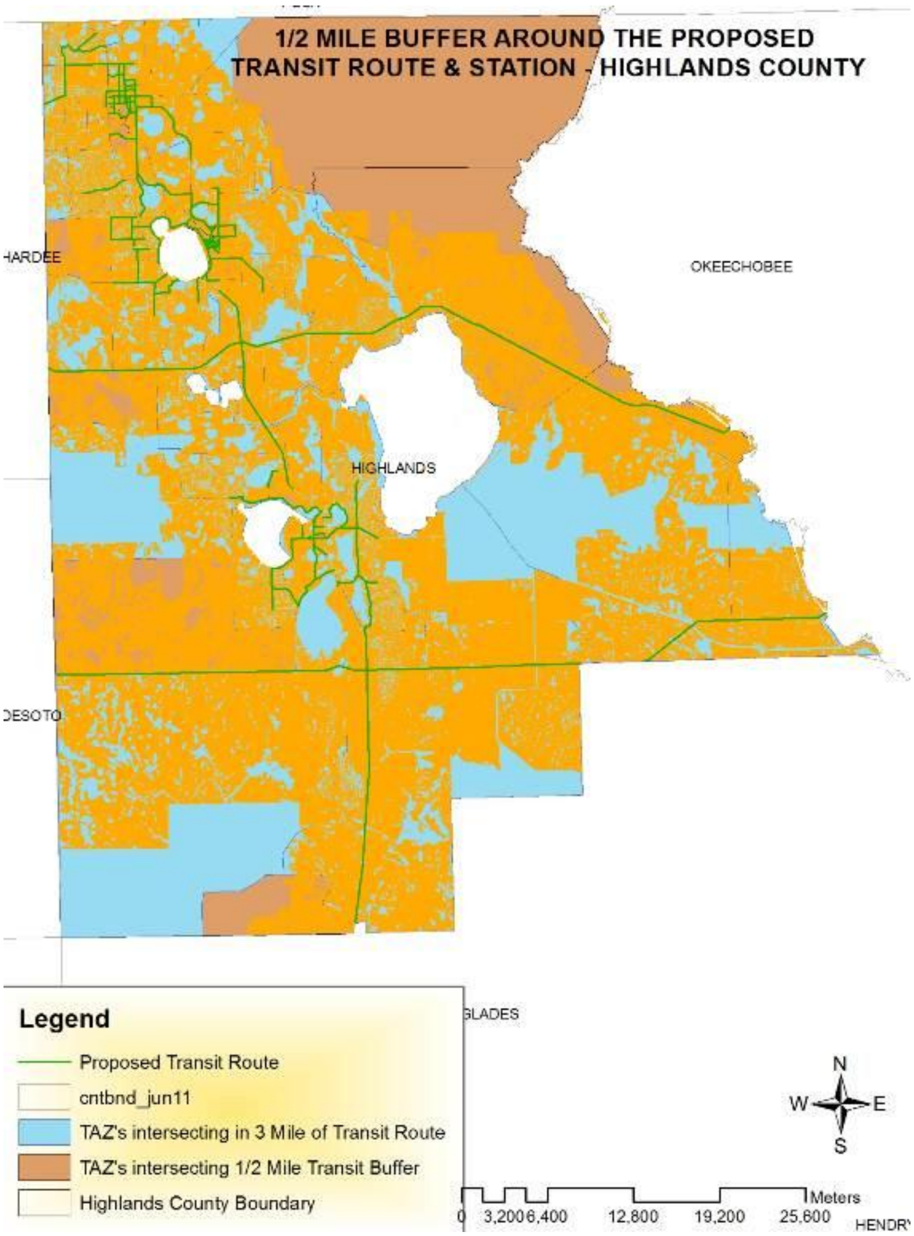


Figure 6-8. Map of half-mile buffer around the transit route in Highlands County, Map Courtesy of Author

Residential density for compact development

The correlation of residential density with almost all measures of urban sprawl and provides opportunities for the potential for change in GHG emissions. Denser residential development tends to increase travel mode shares other than the automobile mode, so that it can contribute to regional automobile VMT reduction by fewer trips and/or shorter trip distances. Therefore, the compactness can be measures within TAZs using the density variable in buffers. The various densities for distributing the population inside the designated buffers act as an indicator for measuring the compactness and is analyzed in the form of Table 6-16 and Table 6-17 shows the average TAZ population and employment densities within the different buffer zones shown in their respective counties. The average TAZ densities are a result of calculating the population and employment densities for each TAZ within a buffer zone and then performing an average of those densities.

Table 6-16. Average TAZ population and employment densities by buffers - Polk County

	Population Densities(People per Acre)			
Buffers	2006 TAZ	2035 Transport Model	Low Density Scenario	Medium Density Scenario
Buffer 1 & 2	2.18	2.87	5.21	7.9
Buffer 3	2.43	3.23	5.7	6.2
Buffer 4 & 5	2.21	3.21	4.20	5.82
Buffer 6	2.35	3.17	3.25	4.8
Remaining County Area	2.28	3	2.50	3.5
		Employment Densities		
Buffer 1 & 2	9.35	9.68	6.9	7.80
Buffer 3	5.15	5.67	5.4	5.80
Buffer 4 & 5	4.20	4.8	4.70	4.65
Buffer 6	4.73	4.60	4.78	4.90
Remaining County Area	3.80	3.60	3.80	3.95

Source: Courtesy of Author

Table 6-16 shows that the average densities for residential population in the both low-density and medium density scenario for Polk County are higher in buffers. The TOD buffers i.e. buffer 1, 2 and 3 (or half-mile distance of transit stops and routes) densities are higher in comparison to the density used by the transportation model scenario for population allocation, indicating a more compact and denser scenario. However, the employment density used by the transportation model for TOD buffer 1 and 2 ,3 is higher than the low and medium density scenario only.

Table 6-17. Average TAZ population and employment densities by buffers - Highlands County

	Population Densities (People per Acre)		
Buffers	2006 TAZ (People per Acre)	2035 Transport Model	LUCIS based future scenario
Buffer 1 & 2	5.50	6.10	7.90
Buffer 3	4.70	5.20	5.50
Buffer 4 & 5	5.50	6.31	6.35
Buffer 6	4.60	5.07	5.05
Remaining County Area	0.80	2.10	3.25
	Employment Densities		
Buffer 1 & 2	1.40	2.38	2.50
Buffer 3	2.09	2.12	2.30
Buffer 4 & 5	1.3	2.21	2.30
Buffer 6	1.29	2.00	2.10
Remaining County Area	0.08	0.64	0.85

Source: Courtesy of Author

Table 6-17 shows that the average densities used in the LUCIS based future scenario for Highlands County are comparatively higher in buffers within TOD distance of transit routes than the one used in the transportation model scenario for population allocation, however the employment distribution densities are approximately same for the LUCIS based future scenario.

Analyzing Reduction in Carbon Footprints with Decreasing VMT

The reduction of carbon footprints can be measures with decrease in VMT for a proposed land use pattern with existing pattern. VMT is measure of total number of vehicle miles traveled within a specific geographic area over a given period. The TRB Report (2009) recognizes that the location of more compact development within a metropolitan area is likely to affect the reduction in VMT .Since quantification of actual VMT was not in the scope of this research; various indicators were analyzed to understand the probable impact of alternate scenario on VMT and GHG emissions. These indicators in the form of destination accessibility for new dwelling units, diversity of land uses shows the distribution of population in scenarios that supports development-favoring reduction in VMT over a range of period.

New medium and high-density population near centers /transit stop or transit route

Destination accessibility is one of the important land use factor in determining a household or person's amount of driving, as location is the main reason for increased travel pattern, Destination accessibility describes a given location's distance from common trip destinations and origins. Distance to transit is a measure of travel starting from home or work to the nearest rail station or bus stop by the shortest street route (Cervero and Ewing, 2010, pg.7)

Therefore, analyzing the distribution of population distribution within half-mile buffer distance in comparison of the total distribution for each land use will provide a analysis of destination accessibility of that use and concentration of population within accessible distance of transit. Table 6-18 shows the percentage of new development within the half-mile buffer distance from transit stops and stations in comparison to total population distribution for that particular land use. For example, in case of Polk County, the 50% of commercial population is accommodated within the half mile of transit, with about 38% of MF and 30% of SF population in the same buffer distance, making it accessible for travel and reducing the need to drive automobiles.

Table 6-18. Percentage of medium and high-density population allocated in half-mile area around the transit route in 2035 scenarios – Polk County

Population Distribution	SF	MF	COM	SER	IND
Total allocated Population in TOD buffers - Low Density	71,295	72,880	30,568	71,024	125
Total Population allocated in Low Density Scenario	241,470	193,916	60,026	143,227	1,455
Percentage of New Population in TOD buffers	30	38	51	50	9
Total population allocated in Medium Density Scenario	51666	103051	31763	79298	125
Total Population allocated in Medium Density Scenario	194,290	240,911	61,221	145,931	1,455
Percentage of New Population in TOD buffers	27	43	52	54	9

Source: Courtesy of Author

Table 6-19. Percentage of medium and high-density population allocated in half-mile area around the transit stops in 2035 scenarios - Highlands County

Population Distribution	SF	MF	COM	SER	IND
Total allocated Population in TOD buffers - Low Density	17028	17151	1835	4768	595
Total Population allocated in Alternate Growth Scenario	27,919	41,120	9,760	16,524	2,702
Percentage of New Population in TOD buffers	61	42	19	29	22

Source: Courtesy of Author

Table 6-19 indicates the total percentage of new population assigned in the accessible distance of half-mile buffer area for Highlands County. It is interesting to note that almost 61% of the single-family population is within an accessible distance of half- mile from transit station, reducing the need to drive for traveling.

Diversity of land uses - Dwelling units near transit route

Diversity of land uses shows the various mixes of proposed and existing uses in the scenario, which is also a prediction for the transport and environmental activities predicted in the future. Diversity is a measure of number of different land uses in an area and the degree to which they represent in land area, floor area, or employment. Figures 6-9 and 6-10 shows the various land uses allocated in the half-mile buffer in Polk and Highlands Counties using the LUCIS framework for predicting future scenarios. Using a land suitability method for allocating has made it possible to calculate the diverse uses for compact development, which was very difficult to analyze with traditional transportation models at TAZ level.

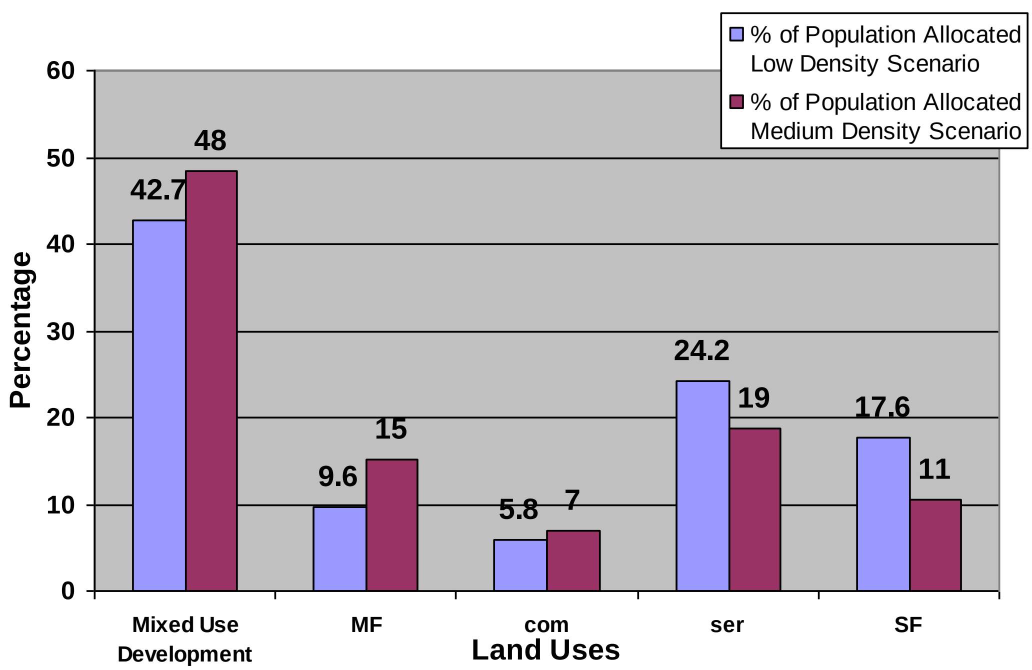


Figure 6-9. Percentage of diverse land uses in Polk County, Chart Courtesy of Author

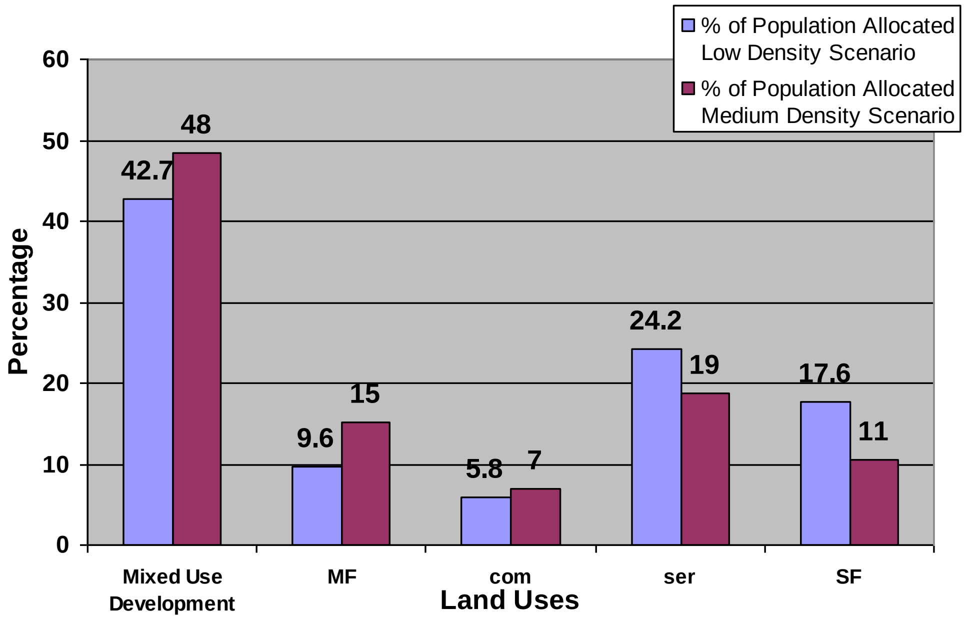


Figure 6-10. Percentage of diverse land uses in Highlands County, Chart Courtesy of Author

Assessing Preservation of Natural Areas and Ecosystems

As the Heartland region aims to promote preservation of natural areas and ecosystem, the LUCIS based scenario uses the same guidelines for the preservation and conservation of these natural areas and ecosystems. The scenarios uses following indicators to compare the conservation and preservation of the lands vital for the future generations like pen spaces consumed by development in terms of occupied population proportions, high value conservation land saved/consumed by development, high value agriculture land saved/consumed etc.

Open space consumed by development – Occupied populations proportion

Promoting single-family development is another indicator of increasing sprawl and use of more open spaces, as new single-family development requires open space for construction in terms of cleared lands and forest with increased need for roads and infrastructure. Multi-family development demands less land in terms of open spaces, with increased density accommodating more people than the single family. However, the need for roads and infrastructure is required for both development, but is concentrated in to smaller areas for multi-family making it a compact development.

Table 6-20 provide a detailed distribution of population in single family and multifamily development for the low-density and medium density scenarios for the Polk County, in comparison to the 2035 MVP scenario and existing population, as a indicator to understand the usage of open spaces for future development. The trend analysis shows that as the density increases for the scenario, the single-family development is decreasing making it more compact development. The medium density scenario and low-density scenario both reflects less amount of single-family development for the future, promoting more multi-family development to support the goal of compact development and to reduce usage of open spaces to increase sprawl.

Table 6-20. Occupied population proportions – Polk County

Resident Type	Existing % of population	2035 MVP Scenario	% of Population distribution in Low Density Scenario	% of Population distribution in Medium Density Scenario
Single Family	80	84	69	65
Multi-Family	20	16	31	35

Source: Courtesy of Author

Figure 6-11 indicates that the LUCIS based future scenario for Polk County promote more compact development when compared to the 2035 MVP scenario as it allocates more multi-family and mixed use units with low density 15% less SF allocation and Medium density scenario with 21% less SF allocation.

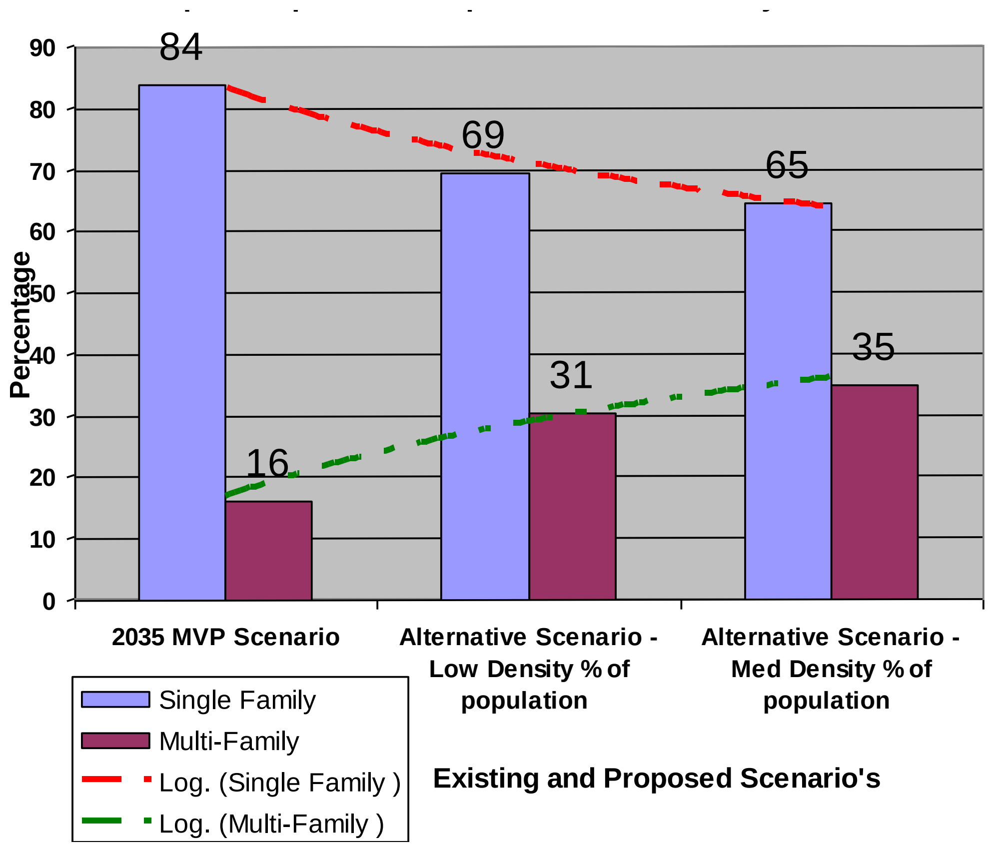


Figure 6-11. Occupied population proportions in Polk County, Chart Courtesy of Author

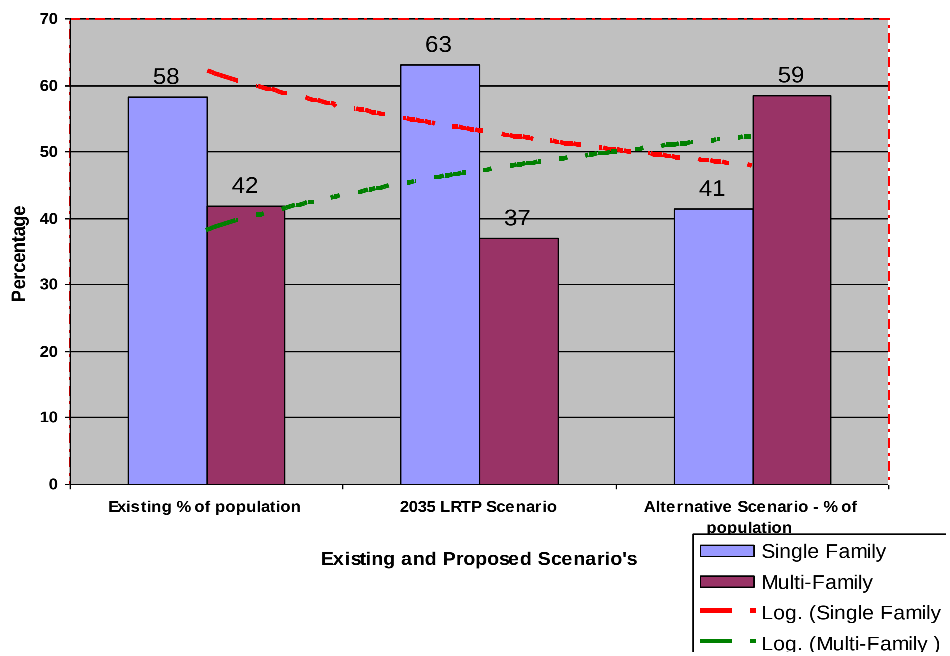


Figure 6-12. Population proportions in Highlands County, Chart Courtesy of Author

Table 6-21. Occupied population proportions – Highlands County

Resident Type	Existing % of population	2035 LRTP Scenario	Alternative Scenario - % of population
Single Family	58	63	41
Multi-Family	42	37	59

Source: Courtesy of Author

The LUCIS based future scenarios in the case of Highlands County is also promoting more compact development with more population allocation in multi-family development and mixed-use development with increase densities as compared to the baseline scenario used for preparation of long-range transportation plan for 2035.

Figure 6-12 indicates the percentages of SF and MF land uses in the form of chart for Highlands County, where the LUCIS based future scenario shows 17% more MF populations than existing scenario and 27% more than the 2035 scenario. It is interesting to note that the population allocation for 2035 scenario in case of Highlands is more than the existing ratio, favoring more single-family development, not in line with the transport decisions.

High-value conservation lands/wetlands consumed/saved by proposed development

For both counties, the high value conservation land could be saved based upon the land suitability analysis. All the high and medium preferred urban areas as identified in the land suitability analysis is developed up to 100%, where as all the parcels identified for high and medium preference suitable for conservation areas is preserved during the allocation process, i.e. no future development is proposed on those identified parcels.

Table 6-22. Preserved and consumed natural conservation areas – Polk County

Conflict Type	Total Parcels in Conflict (Acres)	Vacant parcels in Conflict (acres)	% of Vacant Parcels in Conflict	Percentage Developed (%)	Percentage Saved (%)
High and Med. Urban Preferred in Conflict (112, 113, 123, 213, 223)	11420	590	5.2	100	0
High and Med. Conservation Preferred (121,131,132,231,232)	41265	2190	5.3	0	100
High and Med. Conservation - Urban Conflict(122,133,233)	56013	447	0.8	0.0	100

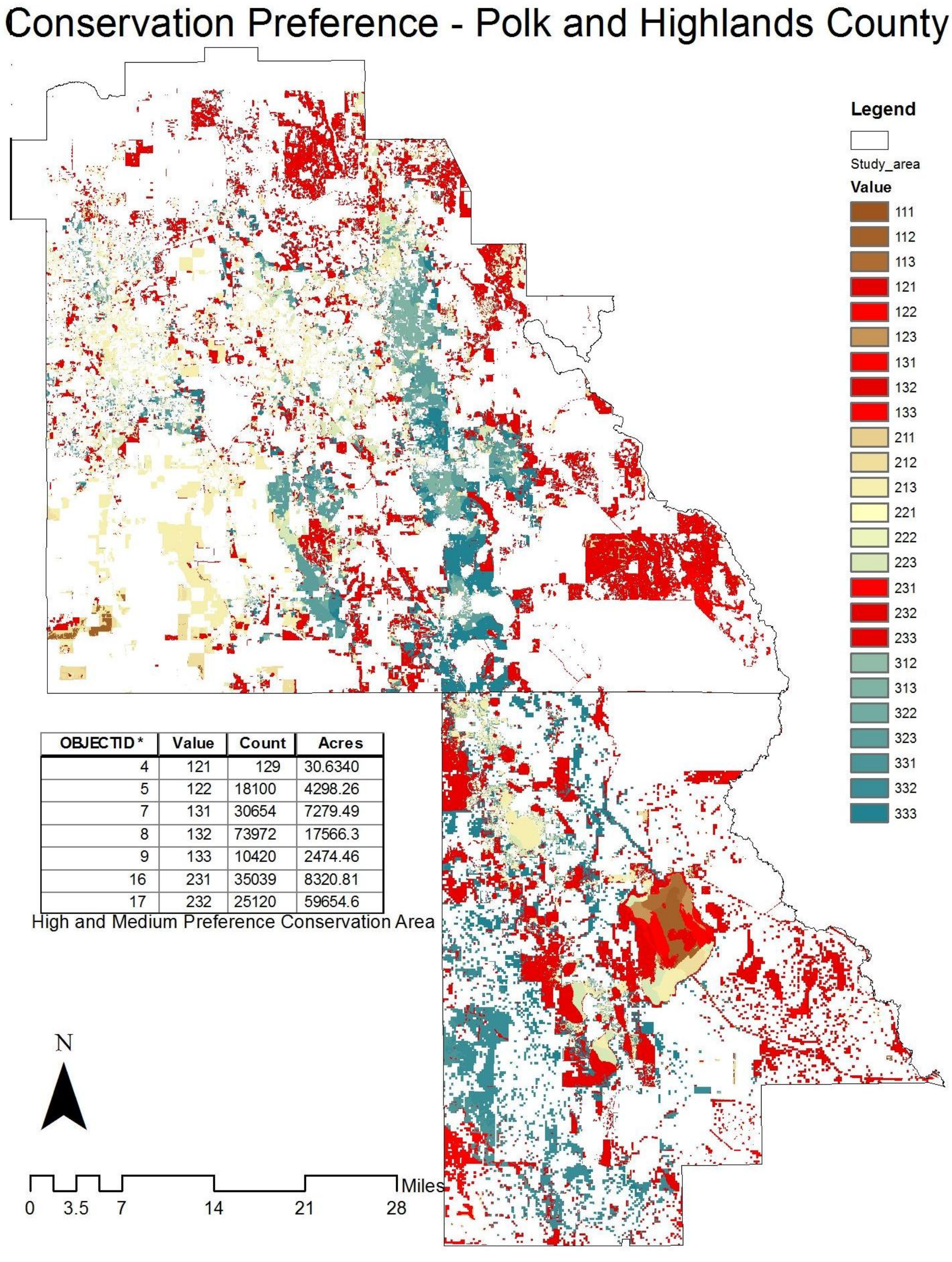
Source: Courtesy of Author

Table 6-23. Preserved and consumed natural conservation areas- Highlands County

Conflict Type	Total Parcels in Conflict (Acres)	Vacant parcels in Conflict (acres)	% of Vacant Parcels in Conflict	Percentage Developed (%)	Percentage Saved (%)
High and Med. Urban Preferred in Conflict (112, 113, 123, 213, 223)	11420	590	5.2	100	0
High and Med. Conservation Preferred (121,131,132,231,232)	41265	2190	5.3	0	100
High and Med. Conservation - Urban Conflict(122,133,233)	56013	447	0.8	0.0	100

Source: Courtesy of Author

Table 6-22 and 6-23 show the percentage of land conserved in Polk and Highlands County with percentage of land developed as per the land suitability analysis criteria's for high, medium preferred lands. Figure 6-13 shows the location of high value conservations lands and its various conflict ranking, detailing the value saved for conservation.



OBJECTID *	Value	Count	Acres
4	121	129	30.6340
5	122	18100	4298.26
7	131	30654	7279.49
8	132	73972	17566.3
9	133	10420	2474.46
16	231	35039	8320.81
17	232	25120	59654.6

High and Medium Preference Conservation Area

Figure 6-13. Map showing suitable conservation lands in Polk and Highlands County, Map Courtesy of Author

Assessing agricultural land

Agricultural land is often first choice of builders and developers for extending urbanization or creating new urban land. In shortage of suitable urban land when considering future development, often agricultural land in proximity to urban land is opted for developing the urban land further, as its easier ton increase the available road and infrastructure facilities nearby a urban development . Mostly agricultural lands are opted for rezoning to development land, which may be of high importance to crops and agriculture practices, without considering their agricultural value and suitability for development. Both Polk and Highlands County are highly dependent on agricultural resources for their economic engine; hence, land suitability in order to determine the areas suitable most for the agricultural land plays an important role here. Table 6-24 and 6-25 show opportunity for up to 57% of the agriculture land in Polk County and approximately 30% in Highlands County to be preserved for agricultural development.

Table 6-24. Preserved and consumed agricultural lands - Polk County**.**

Conflict Type	Total Parcels in Conflict (Acres)	Vacant parcels in Conflict (acres)	% of Vacant Parcels in Conflict	Percentage Developed of Vacant Parcels (%)	Percentage Saved (%)
High and Medium Preferred Agriculture Land (211, 311, 312, 321,322)	49732	10662	21.4	0	100
High and Med. Agriculture - Urban Conflict(212, 313, 323)	64832	36940	57.0	44.5	55.5

Source: Courtesy of Author

Table 6-25. Preserved and consumed agricultural lands - Highlands County.

Conflict Type	Total Parcels in Conflict Acres)	Vacant parcels in Conflict (acres)	% of Vacant Parcels in Conflict	Percentage Developed of Vacant Parcels (%)	Percentage Saved (%)
High and Medium Preferred Agriculture Land (211, 311, 312, 321,322)	1090	330	30.3	0	100
High and Med. Agriculture - Urban Conflict(212, 313, 323)	33209	8930	26.9	22.0	78.0

Source: Courtesy of Author

Summary of Results

In both the counties, the LUCIS based future scenarios using the land suitability method (LUCIS) shows the opportunity for a higher percentage of compact urban growth patterns in Polk and Highlands Counties. In case of Polk County, the medium density scenario is even more compactor than the low density scenario, however both the scenarios exceed in terms of compactness when compared to the scenario proposed by the 2035 mobility vision plan – long range transportation plan by Polk County . The Highlands County LUCIS based future scenario also creates a more compact scenario when compared to the proposed scenario by the long-range transportation plan for Highlands County in 2035.

When compared at a 3-mile buffer for transit zones, with TAZ level data available for both counties, the LUCIS based future scenarios (low-density and medium-density scenario for Polk County and alternate scenario for Highlands County), shows more compact population density pattern than the proposed scenarios. The medium density scenario for Polk projected 64% of population inside the 3-mile buffer, whereas the low-density scenario projected 61% of total population inside the 3-mile buffer. The comparison of the 3-mile buffer population is with the population predicted by baseline scenario of the respective county LRTP based on TAZs. In the case of Highlands County, almost 80% of total population can reside inside the 3-mile buffer zone, making it a compact development.

The comparison of residential densities for LUCIS based scenarios to the baseline scenarios predicted by their respective counties in the designated buffer areas show a general trend that the population allocation uses higher densities in the buffer of quarter mile to 1-mile distance when compared to TAZ residential densities in both the counties.

The analytical assessment of natural areas and conservation lands in the counties also indicates that the LUCIS based future scenario , that relies on land suitability technique shows that all the high preferred conservation areas critical to the habitat pertaining to each individual counties can be identified and saved if the future development pattern is changed to a higher-density, transit-oriented pattern. In the LUCIS based future scenarios, the identified land critical for conservation was designated as no-development areas. The scenario also confirms the opportunity to preserve the high value agriculture land for future agriculture production. The agricultural areas with high preference for both agriculture and urban (conflict areas) shows that only 44.5% of vacant land parcels in conflict with agriculture and urban areas in Polk County and 22% of vacant land parcels in conflict with agriculture and urban areas is utilized in Highlands County to accommodate excess population for 2035 scenarios.

CHAPTER 7
DISCUSSIONS

Findings and Methods

Together, the land use and transportation network interact to affect destination accessibility (ease of travel between trip origins and desired destinations) and distance between development and transit (Bartholomew & Ewing, 2009). To accomplish these goals will require attention to details of the land development and, particular density, mix or diversity of land uses, concentration of development into centers, spatial arrangement of land uses, and street design and connectivity. The transportation network dimensions include the spatial patterns of the transportation system (whether the networks are sparse or dense, grid like or hierarchical).

Applicability to Research

This study shows that allocating urban growth near proposed transit routes with an aim to increase use of public transit system using a thoughtful method of allocating future land use based on land use suitability analysis and scenario-planning techniques provides a more sustainable prediction tool for long range planning. As learned from the literature and analytical results of the research study, LUCIS based future scenarios for both counties, proposes a development pattern that is compact, sustainable for future generation with sensible approach for preservation and conservation, The scenarios also predicts the possibility of greater reductions in VMT and GHGs than a historical trend model that allocate future growth. Integrating the allocation decisions based on the suitability and careful land analysis along the future transit route provides more compact development pattern and can lead to better transportation decisions for future generations.

In the preparation of these future scenarios for the long range plans, many intermittent stages are involved like creating a vision, providing guidelines for development in terms of TOD development, along with an ultimate goal for the scenario in terms of compact development, sustainable development etc. Applicability and success of the scenario in the future will depend on the correct integration and implementation of these stages and strategies for the scenario development. The following section discusses some of the stages and strategies in terms of importance's and constraints in the implementation.

Importance of Regional Vision

The regional vision belongs to an entire community; people living in the community should be active participants in the development of alternative and their evaluation. . Any attempt to force a particular vision on a community may end in conflict. The involvement of local citizens in the visioning process in a timely manner can result in a vision, with public preferences and will be useful for building a successful community. The visioning process also educates the public in the complicated interrelationships between natural resources, urban development, transportation, land development and redevelopment, and community social structure. Involvement of the public in visioning makes ensures it is more likely to be implemented. The research revolves around the vision for both counties, as the counties aim to promote compact development in their long-range plans.

For example, promoting TOD for a future scenario is a vision for a particular county and is a great step towards the goal of compact development. But implementing a TOD project involves lot of changes at policy and land use level of county; it also requires better coordination for land use decisions with transport projects. Therefore, it is imperative to understand the constraints in implementation of this vision, as it involves the financial part of strategy. The next section discusses the financial constraint in implementing the TOD for a proposed scenario.

Overcoming the Financial Constraints in Planning for TOD

Financial constraints are also barriers to broadening the scope of transportation planning and project development to include livability. Promoting mixed development along the transit system using concepts of TOD is an ideal method to integrate land use and transportation; however, it is an expensive process and require different development patterns like transit based development which in uncommon in Florida. Since TOD is a comprehensive development, it requires large-scale investments in both capital and operations of transit systems. Public funds may not be sufficient to finance the whole project and may need to share the burden with private partnerships or use other funding techniques. Sometimes, despite the intentions of stakeholders to implement the TOD, the local economy may not be suitable to implement it (Cervero et al., 2004, Boarnet & Compin, 1999 as cited in Reddi, A., Chattopadhyaya, S., Mazumder, T., n.d).

This study shows the importance of developing TOD in terms of compact residential and commercial development for enhanced quality of life and economic progress along a transit route and development around half-mile of transit stations. In other words, TOD requires both the transit and the compact development that orient around it. The financial costs associates with TOD at implementation level are often a major setback for the success of TOD projects. Other issues like political changes, and socio-economic and demographic changes, along with the planning period for conceiving the TOD plan and the actual implementation are also factors that need in consideration for the future scenarios and its success.

Compact Development and Reduction in VMT – Degree of Measure

The literature on urban form and travel suggest that they are intricately linked with several land use characteristics like the 5Ds –density, diversity, design, access to regional destinations, and distance to transit – have the potential to increase the use of public transportation, and the levels of walking and bicycling, and reduce automobile dependency (TRB, 2009).

The research indicates that the LUCIS based future scenarios for both counties where the allocation was based on proximity to future transit and transit stops has the potential to create a compact development pattern, which is more compatible with long-range transportation planning goals of reducing automobile distances and shifting to other modes of travel. This potential is indicated at two levels, with the potential for an average of 65% of the population to live with a half-mile buffer area along the entire transit corridor and transit stops and the potential for an average of 60% of the population to live within the 3-mile buffer distance for all scenarios. The half -mile distance is considered a walking distance, while the 3-mile buffer distance is considered as a park and ride distance or a bicycling distance from the transit stops.

The scenario allocates the populations along the proposed transit routes and transit tops, assuming that the transit facilities can encourage reduction in driving habits, thus reducing the VMT and GHG emissions. Therefore, the following section discusses the impacts of introducing a transit service to the transportation scenarios and its impacts.

Introducing the Public Element – Growth around the Proposed Transit route

Transit can carry many more people per gallon of fuel than can autos; therefore substantially increasing transit use might significantly reduce GHG emissions (A.T. Moore et al., 2010)

The LUCIS based future scenarios used this distances from transit stops or routes as a major factor in allocating future land use and urban growth, whereas the trend scenario used by the counties for preparation of long range plans seems to be focusing more on concentrating growth around existing and proposed activity center, regardless of their proximity to proposed transit. This is an important land use and transport integration issue, which can have significant impacts on the future decisions by the MPO, the counties and the cities in Highlands and Polk Counties

The need assessment based LUCIS based future scenarios in the study created with a focus of locating people compactly around the transit routes in both Polk and Highlands Counties. The scenarios present a picture where the development proposed along a visionary transit can produce more balanced and compact development, aimed to promote increased use of transit system. This could lead to a reduction in single occupancy vehicles, which can prove to be a very important factor while considering the reduction in VMT and GHG emissions due to VMT.

Along with introducing the transit services in long range planning, shaping the development pattern around the transit system can play a vital role in scenario planning, as the concentration of population in proximity to transit services results in achieving a compact and denser land development. The following sections discuss the same concept in detail with respect to the research study and its scenarios.

Proximity to Transit and Employment Densities

The literature review undertaken by the TRB (2009) reported that proximity to transit and employment densities at trip ends has a stronger influence on transit use than urban design features such as walk ability and land use factors such as mixed uses and increased residential densities.

Although this study was unable to quantify the transit use or increase in transit rider ship, the LUCIS based future scenarios was able to allocate greater proportions of population and employment in closer proximity to future transit, which can lead to reduction in VMT due mostly to residential and employment land uses in closer proximity to each other.

The proximity to transit also results in increased transit rider ship, depending on the effective of transit services in planning and implementation. The most well-conceived TOD strategies cannot increase rider ship effectively, unless it is a part of a larger system that situates the origins and destinations of transit trips (such as home and work) in proximity to transit stops.(Transit and VMT Reduction, (n.d) Para. 9). The coming section discusses the needs for increasing the transit rider ship and its impact on the environment.

Increased Transit Rider ship

Evidence from the literature review undertaken by the TRB in 2009 indicates that proximity to transit has a strong influence on transit use, as does the employment densities at trip ends (p. 47). The research did not evaluated the transportation model with proposed transit routes as the work was out of scope due to time and data constraints, but the research did looked in to the proposed transit models by the respective counties on the proposed transit routes with transit options. The 2035 MVP for Polk County uses the base forecasted for 2060 shifting focus from private auto to transit needs with bus and commuter rail provisions. The 2035 scenario – Needs Network, which is part of the 2035 MVP document identifies these themes and integrates recommendations for premium service such as BRT and commuter rail needed by 2035. The model shows that the Needs Network is effective in reducing vehicle miles and hours of travel, and results in higher travel speeds and transit rider ship when compared to the 2013 Existing and Committed (E+C) Plus Network. (Refer Table 5-19, Chapter 5 – Defining the need network, 2035 MVP, pg.141)

The LUCIS based LUCIS based future scenario assumes and utilizes the same transit network as modeled in 2035 LRTP, for allocation based on proximity to transit and use of increased employment densities in areas adjacent to transit as guidelines for allocating growth. It is possible therefore; that in future, if the Polk County's visionary transit system is modeled as shown in the LRTP in conjunction with a LUCIS-generated future land use configuration, larger increases in transit rider ship should is possible with reduction in VMT. Similarly, he visionary transit lines for Highlands County, when modeled with the LUCIS based future scenario, will show higher reduction in VMT and GHGs as a probability in comparison to the baseline scenario land use prediction for LRTP.

Limitation of GIS Modeling and LUCIS

The GIS-based scenario planning are not observations or predictions based on the historical trends, they are computer-generated models with assumptions of situations and their future impact in terms of changes in land uses, or travel pattern (A.T. Moore, et al., 2010). This GIS based scenario planning is a careful assessment of the land conditions, and assumptions between predicted travel behavior and land use types with use of GIS tools.

The modeling of scenarios in the research does not consider the costs or feasibility of proposed changes, such as, redevelopment to mixed land use conversion, Brownfield development issues and constraints, and the market for, and impact of, multi-family development on a region. The model works on the principle of assigned densities, which is a unit of population per acre or jobs per acre. The higher social cost of increasing residential or employment density remains isolated and is, thus, not calculated, while allocating the population in a GIS-based model. The model also does not take into account the natural factors like catastrophic disaster in the future, which can influence the land use configuration and population in the future.

Scenario analysis used for transportation demand forecasting, does not consider implementation costs or transaction costs involved in achieving difference scenarios, nor do they calculate the net social costs and benefits of pursuing different land use and transportation options. It is an irony, that most transportation-land use scenarios are developed are without significant public comment.

LUCIS based modeling is based on role-playing to introduce and exaggerate bias with use of suitability analysis. Though the role-playing can be substituted with real public intervention, there is a need to make the modeling process more compatible with real time situations.

CHAPTER 8
CONCLUSIONS

Polk County and Highlands County are expecting an average of 60% of growth in the next 10-15 years, which can overload the current infrastructure and hinder sustainable development. On one hand, Polk County is the economic engine of the region, and faces challenges to incorporate future population growth, conserve its natural character of agriculture with trends of urbanization; while on the other hand, Highlands County is also facing the economic distress including higher unemployment conditions. The whole region is expected to grow at a rapid rate and has sensitive ecological features is making it challenging for the counties to accommodate the growth and facilitate them with basic facilities. Coordinating the land use and transportation decisions for the region will be viable solution for a region, which proposes the vision for compact development for the region.

Research on impact of urban forms on transit use, shows the importance of proximity to transit as an important factor in attracting transit users and promoting compact development. To predict an urban form, which is compatible to future growth and transport decisions, is a challenging task, therefore a more close predictable method for analyzing the future scenario is required to integrate and weave all the important factors.

While and use is a slow process, and transportation decisions are time consuming, the impact of these in terms of cost and operating expenses are huge in addition to the impacts of land use changes. Hence, it is imperative to look for a complete picture when analyzing the future, as it is a two-fold impact. Anticipating the urban form needed to support these long-range transportation decisions and beginning to encourage development in appropriate locations, where the transport investment is intended, will not only allow safe investment options, but will help in shaping and accommodating slow land use changes in the form predicted for sustainable development.

The high investment in terms of road infrastructure is not new to Florida, which is known to have disjointed land use and sprawl development pattern. The state has offer few choice so travel and its residents and visitors have relied on private vehicles and have been highly dependent on single occupancy vehicle, with little or no consideration for the public transit. The availability of land and presence of vast water coasts, made it more difficult to promote the high-density development. Both Polk and Highland Counties show similar pattern with added economic challenges in terms of low employment rate, and population explosion in future.

The aim of the study was to show how thoughtful analysis of land use allocation, with respect to transport decisions, can create a more sustainable community, without compromising the natural areas and preserving the character of the county, and by concentrating future growth in a pattern that supports the social, economic vitality of the counties. . It was tested in the form of hypothesis that a different allocation method, based on sensible use of land based on proposed transport projects with land use suitability analysis and scenario planning techniques, could improve the achievement of mutually supportive land use and transportation goals, integrating them for a more sustainable development. The model can allocate land use at more precise location for future growth that meet specific planning guidelines designed to enhance the coordination of long-range land use and transportation decision, and can also identify and differentiate lands required for conservation and preservation, thus offering the opportunity of saving it for future generations.

The LUCIS method offers a positive alternative to addressing problem based on the issues of time lines for future prediction, as since it anticipates changes in the future land use based on suitability guidelines of how future land use should be configured to transportation planning decisions for a proposed transit. The method is successful in envisioning changes at small-scale level, instead of TAZ level providing a more in-depth analysis and aggregated land uses at a regional level. However, it also may present a false sense of precision because the granular patterns of the analysis may not be consistent with the pattern of land ownership.

This study has also been valuable in highlighting the importance of regional accessibility in the coordination of long-range land use and transportation plans, and in understanding the importance of selecting a right prediction tool for long range planning. It is a challenging task to attract higher densities, aimed at compact development adjacent to future transit systems, when the tools selected for predicting future cannot identify and eliminate roots of sprawl development or regionally isolate land developments. The modeling process, which creates the future scenario gives this prediction of future conditions for the region and is based on needs assessment depending on methods like past trend, suitability analysis etc,. The proposed land use changes and transport projects are also in accordance with it, making it imperative to propose a very realistic scenario to achieve realistic results after implementation of proposed projects. Therefore, it is very important to understand the relationship of proposed development patters with future investment decisions.

Traditionally the future land use map (FLUM) policy designates land as urban future land uses (FLUs) in areas preferred for uses other than urban, which means valuable agricultural and conservation land could be lost or inappropriately developed. The LUCIS based scenario analyzes the development in terms of conflict of areas and preferences and allocates land use based on the results. Therefore, all the conservation lands, which are sensitive to the county is identified and preserved using the LUCIS method for future generations. The study establishes an example of saving areas of natural importance and future assets by eliminating its use for any other purpose and simply leaving it unused as conservation area. The allocation approach in the study as stated earlier, is based on assumption, that land used for allocation to new development will be distributed first to areas of least conflict, and funneled to its most appropriate and preferred locations. The conflict identification enables to highlight areas, which can become threats to agricultural or ecological resources. If the preservation of the identified lands based on the suitability and conflict, as described in the LUCIS process for ecological sensitivity is followed, the patterns of development can be more sensitive towards ecological needs and priority identification for agriculture and conservation lands.

The future scenario for long range planning predicted with use of strategy as LUCIS is compact and shows sensitivity towards the preservation of natural areas and ecosystems by responding to the situation in terms of increasing density and mixed-use population. The scenarios also promote increase in transit rider ship, and a decrease in SOV by using the proposed transit route for land use allocation and assigning the majority of population in the buffers designated under manageable distances from the transit stops and stations. These scenarios if modeled with the transport options show the potential for a higher VMT reduction along with reduction in carbon footprints.

APPENDIX A
LIST OF DATA USED AND AVAILABLE SOURCES FOR BOTH COUNTIES

Table A-1. Name and source of data used for both counties

Population & household estimates – Polk and Highlands County 2007	Tabular	Census Bureau
Traffic analysis zone data – Polk County and Highlands County 2000 and 2010	Tabular and GIS vector	FDOT , Polk County Transport Demand Model, Highlands County Transport Demand Model
Average of medium and high population projections – Polk and Highlands County for 2035	Tabular	BEBR
Employment projections – Polk County & Highlands County– 2010 and 2035	Tabular	Census Estimates from ACS (5 year) – Aggregated by Aserkar for TAZ
Parcel data – Polk County and Highlands County – 2009	GIS vector	Florida Geographic Data Library (FGDL)
Hydrography – Polk & Highlands County – Polk and Highland County ponds	GIS vector	FGDL
Florida Managed Lands – Polk County and Highlands County conservation areas – 2009	GIS vector	FGDL
Developments of regional impact	Tabular and GIS vector	CFRPC, Polk County 2035 Mobility Vision Plan
LUCIS Conservation Suitabilities for Polk and Highlands County – created in 2008-2009	GIS raster	Dr. Tom Hoctor, Geoplan Center,UF
Visionary transit lines and stations for 2035 – Polk and Highlands County	GIS vector	Polk County Transport Demand Model for 2035 and Highlands County Transport Model for 2035.

APPENDIX B
BUFFERS DISTANCES AROUND THE ACTIVITY CENTERS/TRANSIT STOPS IN POLK COUNTY

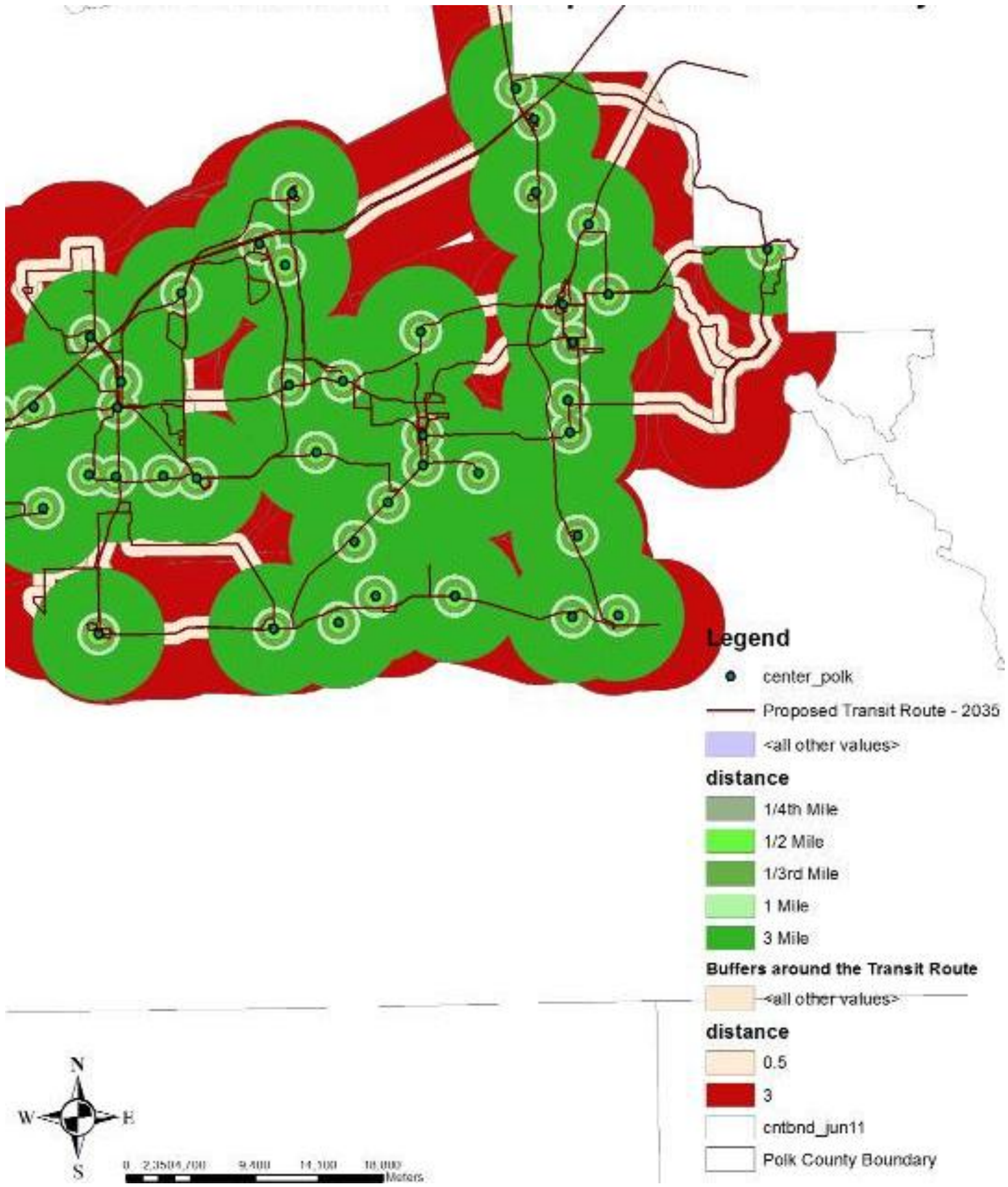


Figure B- 1. Various buffer distances around the transit stops in Polk County

APPENDIX C
BUFFERS DISTANCES AROUND THE ACTIVITY CENTERS/TRANSIT STOPS IN HIGLANDS COUNTY

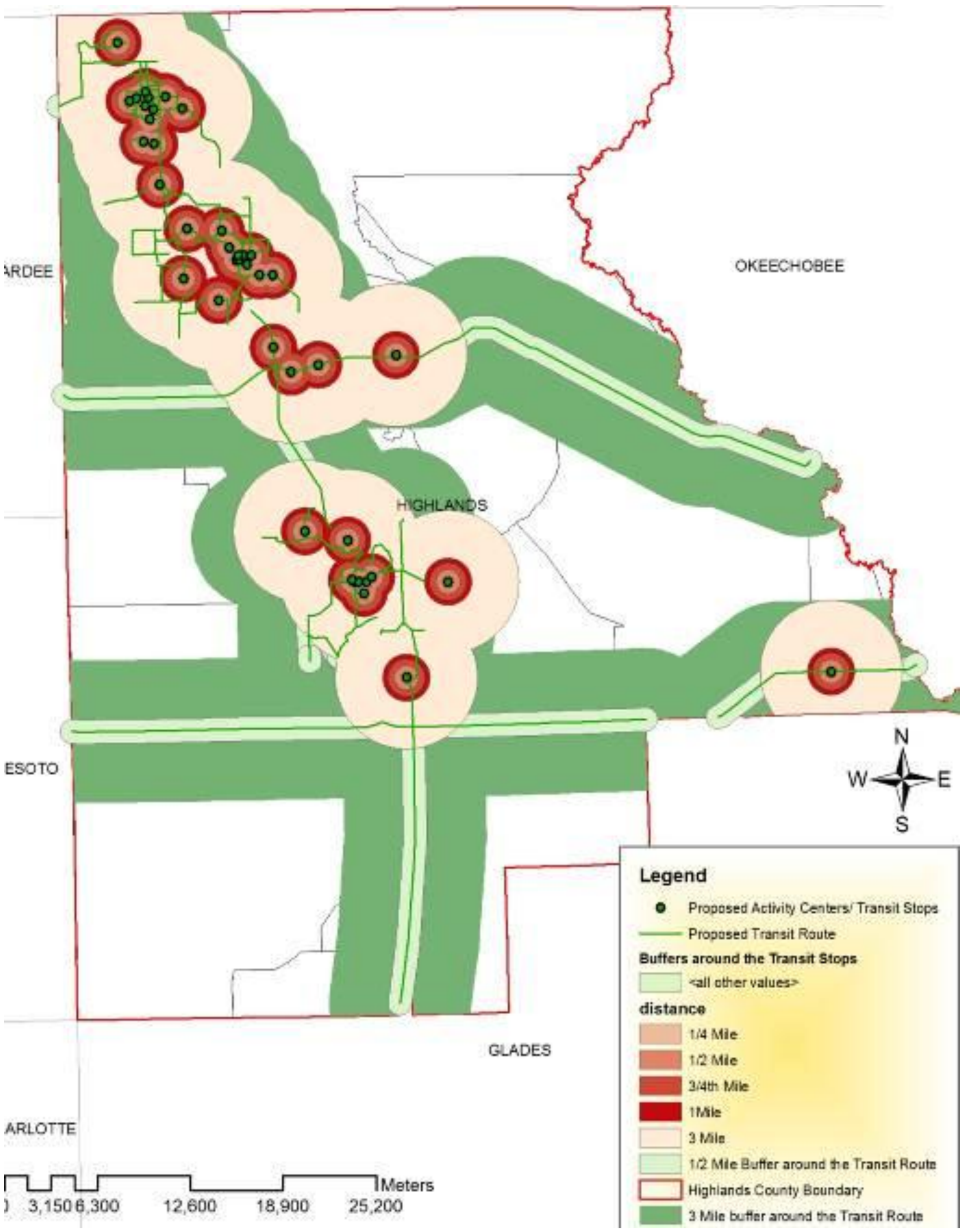


Figure C-1. Various buffer distances around the transit stops in Highlands County

APPENDIX D
AGGREGATION OF FDOR LAND USE CODES IN THE PARCEL DATA TO TAZ LAND USE CODES

Table D-1. List of FDOR codes aggregated to TAZ codes

FDOR	TAZ	FDOR	TAZ
Vacant residential	VACRES	Grazing land	IND
Single family	SF	Poultry, bees, fish, rabbits	IND
Mobile homes	MF	Dairies, feed lots	IND
Multi-family	MF	Orchards, groves, citrus	IND
Condominium	MF	Ornamentals, misc. agriculture	IND
Cooperatives	MF	Mining, petroleum, gas lands	IND
Multi-family < 10 units	MF	Subsurface rights	IND
Vacant commercial	VACCOM	Sewage disposal, borrow pits	IND
Stores one-story	COM	Retirement homes	SER
Mixed use (store/office)	COM	Boarding homes	SER
Department stores	COM	One-story non-professional offices	SER
Supermarkets	COM	Multi-story non-professional offices	SER
Regional shopping malls	COM	Professional service buildings	SER
Community shopping centers	COM	Airports, marinas, terminals	SER
Restaurants, cafeterias	COM	Financial institutions	SER
Drive-in restaurants	COM	Insurance company offices	SER
Repair service shops	COM	Camps	SER
Service stations	COM	Golf courses	SER
Auto repair, service, sales	COM	Hotels, motels	SER
Parking lots, mobile home sales	COM	Churches	SER
Florist, greenhouses	COM	Private/public schools, colleges	SER
Drive in theaters, open stadiums	COM	Private/public hospitals	SER

Table D-1. Continued

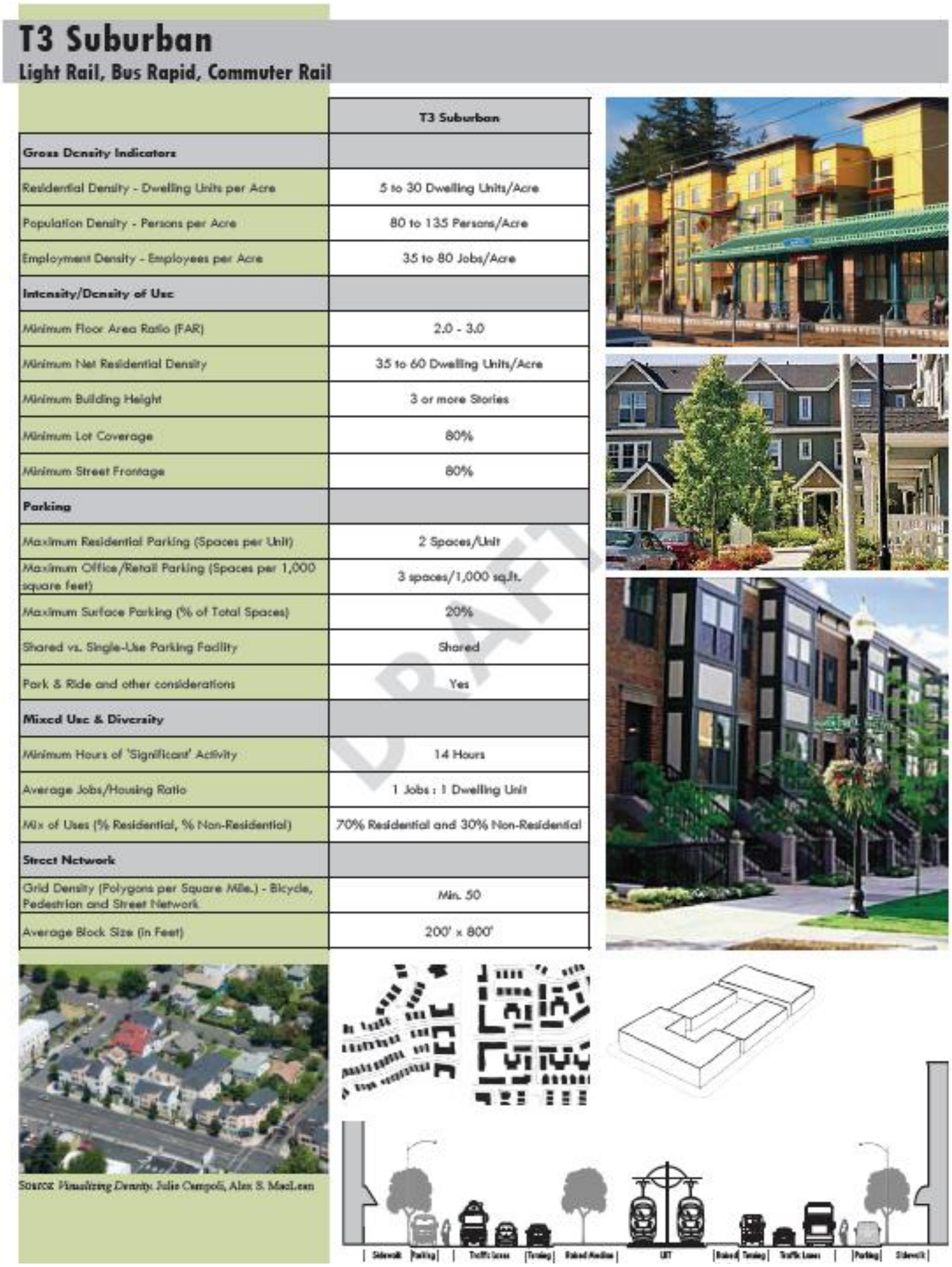
FDOR	TAZ	FDOR	TAZ
Encl. theaters, auditoriums	COM	Homes for aged	SER
Night clubs, bars, lounges	COM	Mortuaries, cemeteries	SER
Tourist attractions	COM	Clubs, lodges, union halls	SER
Race horse, auto, dog tracks	COM	Sanitariums, convalescent	SER
Vacant Industrial	VACIND	Cultural organizations	SER
W/sale manufacture/processing	IND	Military	SER
Light and Heavy Manufacturing	IND	Forest, park, recreation areas	SER
Lumber yards, sawmills	IND	Other – county/state/federal	SER
Fruit, veg and meat packing	IND	Gov. owned and leased	SER
Canneries, distilleries, wineries	IND	Utilities	SER
Other food processing	IND	Outdoor recreational	SER
Mineral processing	IND	Acreage not zoned for agric.	VAC
W/houses, distribution centers	IND	Vacant Institutional	VACCOM
Industrial storage (fuel, equip)	IND	Undefined	No use
Improved agriculture	IND	Rights-of-way, streets, roads	No use
Cropland	IND	Rivers, lakes, submerged land	No use
Timberland	IND	Centrally Assessed	No use

APPENDIX E
AGGREGATION OF CENSUS RESIDENTIAL AND EMPLOYMENT CATEGORIES TO TAZ LAND USE RESIDENTIAL CATEGORIES

Table E-1. List of aggregated census data to residential category

CENSUS RESIDENTIAL CATEGORIES	AGGREGATED RESIDENTIAL CATEGORY
Owner occupied:	
1, detached or attached	Single Family
2 to 4	Multi -Family
5 or more	Multi -Family
Mobile home	Mobile Home
Boat, RV, van, etc.	Mobile Home
Renter occupied:	
1, detached or attached	Single Family
2 to 4	Multi -Family
5 or more	Multi -Family
Mobile home	Mobile Home
Boat, RV, van, etc.	Mobile Home
CENSUS EMPLOYMENT CATEGORIES	AGGREGATED EMPLOYMENT CATEGORIES
Civilian employed population 16 years and over	Ser
Agriculture, forestry, fishing and hunting, and mining	Ser
Construction	Com
Manufacturing	Com
Wholesale trade	Ind
Retail trade	Com
Transportation and warehousing, and utilities	Ser
Information	Ser
Finance and insurance, and real estate and rental and leasing	Ser
Professional, scientific, and management, and administrative and waste management services	Ser
Educational services, and health care and social assistance	Ser
Arts, entertainment, and recreation, and accommodation and food services	Com
Other services, except public administration	Ser
Public administration	Ser

APPENDIX F
FDOT TOD DESIGN STANDARDS USED AS GUIDELINE – T3 FOR POLK COUNTY,


T3 Suburban
Light Rail, Bus Rapid, Commuter Rail

	T3 Suburban
Gross Density Indicators	
Residential Density - Dwelling Units per Acre	5 to 30 Dwelling Units/Acre
Population Density - Persons per Acre	80 to 135 Persons/Acre
Employment Density - Employees per Acre	35 to 80 Jobs/Acre
Intensity/Density of Use	
Minimum Floor Area Ratio (FAR)	2.0 - 3.0
Minimum Net Residential Density	35 to 60 Dwelling Units/Acre
Minimum Building Height	3 or more Stories
Minimum Lot Coverage	80%
Minimum Street Frontage	80%
Parking	
Maximum Residential Parking (Spaces per Unit)	2 Spaces/Unit
Maximum Office/Retail Parking (Spaces per 1,000 square feet)	3 spaces/1,000 sq.ft.
Maximum Surface Parking (% of Total Spaces)	20%
Shared vs. Single-Use Parking Facility	Shared
Park & Ride and other considerations	Yes
Mixed Use & Diversity	
Minimum Hours of 'Significant' Activity	14 Hours
Average Jobs/Housing Ratio	1 Jobs : 1 Dwelling Unit
Mix of Uses (% Residential, % Non-Residential)	70% Residential and 30% Non-Residential
Street Network	
Grid Density (Polygons per Square Mile.) - Bicycle, Pedestrian and Street Network	Min. 50
Average Block Size (in Feet)	200' x 800'

Source: *Visualizing Density*: Julie Campoli, Alex S. MacLean

Figure F-1. Design standards by FDOT, Source - FDOT guidelines for TOD development

APPENDIX G
FDOT TOD DESIGN STANDARDS USED AS GUIDELINE – T2 FOR HIGHLANDS COUNTY

T2 Rural
Express Bus

	T2 Rural
Gross Density Indicators	
Residential Density - Dwelling Units per Acre	5 to 10 Dwelling Units/Acre
Population Density - Persons per Acre	25 to 50 Persons/Acre
Employment Density - Employees per Acre	5 to 10 Jobs/Acre
Intensity/Density of Use	
Minimum Floor Area Ratio (FAR)	.5 - 1.0
Minimum Net Residential Density	10 to 20 Dwelling Units/Acre
Minimum Building Height	2 Stories
Minimum Lot Coverage	50%
Minimum Street Frontage	70%
Parking	
Maximum Residential Parking (Spaces per Unit)	2 Spaces/Unit
Maximum Office/Retail Parking (Spaces per 1,000 square feet)	4 spaces/1,000 sq.ft.
Maximum Surface Parking (% of Total Spaces)	40%
Shared vs. Single-Use Parking Facility	N/A
Park & Ride and other considerations	Yes
Mixed Use & Diversity	
Minimum Hours of 'Significant' Activity	N/A
Average Jobs/Housing Ratio	1 Job : 2 Dwelling Units
Mix of Uses (% Residential, % Non-Residential)	90% Residential & 10% Non-Residential
Street Network	
Grid Density (Polygons per Square Mile.) - Bicycle, Pedestrian and Street Network	N/A
Average Block Size (In Feet)	N/A

Source: *Visualizing Density*: Julie Campoli, Alex S. MacLean

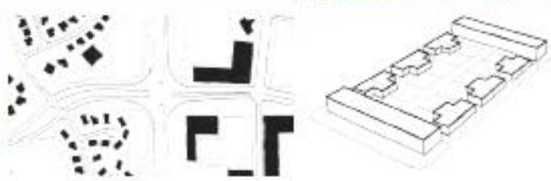


Figure G-1. Design Standards by FDOT, Source - FDOT guidelines for TOD development

APPENDIX H

LIST OF COMBINE RASTERS AND INPUTS

Table H-1. Combinations of rasters as inputs used in the combine process

	Suitabilities										
Buffer Distance	Single Family	Multi-Family	Com	Indus.	Inst.	Retail	Service	Redev.	Mixed use	Redev. Raster	TAZ Numbers	Future Land use data
1/4 Mile from Transit Station	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
1/2 Mile From Train Station	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
1/2 Mile from Transit Route (Excluding Train Station)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3/4th Mile from Transit Station	✓	✓	✓	✓	✓	✓	✓	–	–	–	✓	✓
1 Mile from Transit Station	✓	✓	✓	✓	✓	✓	✓	–	–	–	✓	✓
3 Mile from Transit Station	✓	✓	✓	✓	✓	✓	✓	–	–	–	✓	✓

APPENDIX I
SELECTION CRITERIA FOR POPULATION ALLOCATION

Table I-1. List of selection criteria used for allocating population in both counties

Criteria Applicable	Next Criteria Applicable	TOD Area - Buffer 1	TOD Area - Buffer 2	Buffer 3	Buffer 4	Buffer 5	Buffer 6	Remaining Area of County
For all Redevelopment Parcels, with MXD = 9, I,e all in high preference	Allotment using High preference areas	✓	✓	✓	–	–	–	–
For all Redevelopment Parcels	Opportunity to increase Residential Density in Redevelopment Areas for half mile area – Remaining Redevelopment(areas < 1 ac) Select SF,MF & VACRES allocate @ trend MF density	✓	✓	✓	–	–	–	–
Res. Opportunity Outside Redevelopment for remaining vacant parcels	SF Opportunity – select VACRES and using conflict & sliced SFSUIT allocate to most suitable (conf = 113, 112, 123, 213 or 223 and highest SFSUIT)	✓	✓	✓	–	–	–	–

Table I-1. Continued

Criteria Applicable	Next Criteria Applicable	TOD Area - Buffer 1	TOD Area - Buffer 2	Buffer 3	Buffer 4	Buffer 5	Buffer 6	Remaining Area of County
Employment Opportunity Outside Redevelopment for remaining Vacant parcels	Emp. Opportunity Outside Redevelopment– select high urban pref (conflict = 113, 112, 123, 213, 223) – allocate VAC, VACCOM, to 75% SER and 25% COM trend densities	✓	✓	✓	–	–	–	–
	Infill opportunity & increase in employment density – VACCOM and VACRES to SER @ MU density;	✓	✓	✓	–	–	–	–
Vacant Parcels with High Preference for Urban Areas		✓	✓	✓	✓	✓	✓	✓
Vacant Parcels with High Preference for Urban Areas		–	–	–	✓	✓	✓	✓
Vacant Parcels with Medium Urban Preference		–	–	–	✓	✓	✓	✓

Table I-1. Continued

Criteria Applicable	Next Criteria Applicable	TOD Area - Buffer 1	TOD Area - Buffer 2	Buffer 3	Buffer 4	Buffer 5	Buffer 6	Remaining Area of County
Vacant Parcels in Conflict with High Urban Preference and High Agriculture Preference	-	–	–	–	–	✓	✓	✓

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BIOGRAPHICAL SKETCH

Shivani Aserkar was born in Indore, India in a family that strongly supports the valve of education in life. As a youngest in family with two elder sisters, she always demonstrated high academic capability and inclination towards the eagerness to acquire further knowledge. She received bachelor's degree in Architecture and was awarded national level scholarship to pursue her master's in Urban Planning from an accredited organization in New Delhi. Later she worked as a development consultant to an international firm, where she got interested in international planning related to transportation. After getting married, she migrated to United States of America, where first she worked as an architect, later continued as a planner in a civil engineering firm, and developed keen interests in technical aspects of GIS and Transportation Planning, hence decided to pursue her master's in planning focusing the transportation sector.

She got her master's of Urban and Regional Planning in summer of 2012, and she intends to work as a Transportation Planner with GIS analytical capabilities in Florida, where she currently stays with her husband and 2.5-year-old son.