BUS RAPID TRANSIT AND HEAVY RAIL: A COMPARISON FOR TRANSIT-ORIENTED DEVELOPMENTS IN SOUTH FLORIDA

By

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To my family

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Transit-oriented developments have been embraced by cities across the United States to create dense, walkable, transit-supportive areas. This thesis studies Florida's East Coast (FEC) Corridor to determine which mode of transit, heavy rail or bus rapid transit (BRT), will most likely create successful transit-oriented developments (TOD) in Palm Beach, Broward and Miami-Dade County. As in many transit studies in the United States, Florida's Department of Transportation (FDOT) is completing a study to determine if BRT or heavy rail should be the locally preferred alternative for the FEC corridor as part of the alternatives analysis. But due to the lack of research and information about BRT, planners, government officials and citizens are hesitant to use this system, giving it an unfair disadvantage. In this thesis, transit characteristics that are crucial for creating successful TOD and transit systems are identified. The identified transit characteristics are: land use impacts, frequency, air and sound pollution, vibration, flexibility of service, transfers, capacity, level of permanence, and aesthetics. Comparing BRT and heavy rail based on these transit characteristics in conjunction with the current and forecasted population and employment density for the South Florida

region, it is found that bus rapid transit is the superior mode. Thus BRT should be implemented to help create successful TODs in South Florida. Furthermore, the BRT system also has the potential to create successful TOD in other regions of the United States, especially in areas that lack high density to support heavy rail.

CHAPTER 1
INTRODUCTION

In South Florida, there is a movement through initiatives such as the Eastward Ho to promote urban infill along the coastal regions. Creating transit-oriented developments (TOD) is considered to be an effective tool for creating urban infill that also promotes transit systems (Cervero, 1998). Florida's Department of Transportation is currently conducting research for transit options along Florida's East Coast Corridor in order to provide local transit service in South Florida. When alternatives analysis is conducted for a transit system, many factors are investigated such as: to what degree does the system impact the environment and what is the capital and operational cost of the system. Based on this information along with other factors, a locally preferred alternative is chosen. This alternative is then submitted to the federal government to qualify for and possibly receive the Federal New Starts Funds which covers up to 80% of the capital cost for the system. Yet many times, it is not considered which mode of transit will most likely encourage urban infill and TOD, even if this is the goal as in South Florida.

TOD can be defined as places where different land uses such as residential are zoned with commercial, and these areas are adjacent to public transit stations. The capacity of a transit system to create TOD is an important factor to consider because in order for a transit system to be successful, there must be sufficient population density and commuters must be able to reach local amenities. Dittmar says that "if transit is not convenient, not appropriately frequent, and not linked with the desired destinations so local riders can easily access it, then the transit-oriented aspect of the development will fail" (2004, p.30). If transit takes passengers to a parking lot where they will need to drive miles to reach a grocery store, the system will not be successful. This is a scenario that is often the case with sprawled developments with low density; hence local governments must intervene on some level in this process by implementing policies that create incentives for dense developments. Furthermore, by implementing transit-oriented developments in an area, both transit ridership and the creation of dense developments can be addressed (Dittmar, 2004).

Creating a TOD and implementing a transit system that intersects the central business districts (CBD) of West Palm Beach, Ft. Lauderdale and Miami may be beneficial for South Florida. Tri-Rail, a commuter rail system located west of I-95 provides service to the three counties, but it does not serve the central business districts of these cities. It is located in areas with lower density compared to the CBD of these cities and in order to access Tri-Rail, passengers either need to live in the area or drive and park their cars at the allotted parking spaces provided at each station. This effectively eliminates the chance of providing high-capacity transit service to those who cannot drive, own a vehicle, or live in the low-density areas.

Transit service along the FEC has the potential of allowing residents in the study area to travel without depending on automobiles. Parents may not have to worry about dropping off and picking up their children from school since the area will be pedestrian-friendly with easy access to transit. Furthermore, the more sprawled developments are, the worse air quality tends to be for that region (Hansen & Giuliano, 2004). Having TOD and a transit system could help improve air quality in South Florida since fewer cars could need to be on the congested roads and people may have to travel shorter distances to get to their destinations.

CHAPTER 2
LITERATURE REVIEW

Understanding Transit Oriented Development (TOD)

Before the invention of any form of mass transportation, U.S. cities and cities around the world were highly agglomerated, where people clustered near their jobs and other activities in the town center. The wealthy could afford the luxury of escaping the dense urban cities by commuting with horse carriages, creating pockets of developments known as the suburbs (Hansen & Giuliano, 2004). As cities began to become more industrialized, with large groups of immigrants overpopulating the cities, the middle class's desire to move out to the suburbs grew stronger and so did the pressure to improve intra-urban technology. First there was the invention of the omnibus that proved to be impractical. Then in 1892, New York City "mass" transit was provided to the urbanites, in the form of the horse-drawn streetcar which in turn created "horsecar suburbs" (Hansen & Giuliano, 2004). Demand for these suburbs grew and central business districts (CBD) were created in the form of downtowns where specialized commercial, retail and other services were easily accessible by the horse-drawn streetcars (Hansen & Giuliano, 2004).

Technology was advancing in the industrial era, and in 1888, the first electric trolley line was created. Quickly following this invention, urban fringes where the streetcar provided transit began to become developed. During the early 1900's, cities like Los Angeles, New York City, Boston, Philadelphia, and Chicago constructed rapid rail lines with heavy rails providing mass transit, and these construction projects were nearly completed by the 1920's (Hansen & Giuliano, 2004). Around these rail stations and rail lines, developments grew rampantly with high densities and mixed use. Hence, the idea of TOD is not a new concept. Though this term has been coined recently, this pattern of growth was replicated by urban areas until ownership of private automobiles in America became widespread. But not everyone could afford to buy a car. As Robert Cervero expressed in his book *The Transit Metropolis*:

> Among the most troubling concerns about a car-dependent society are the social injustices that result from physically and socially isolating significant segments of society. Those who are too poor, disabled, young or old to own or drive a car are effectively shut out of society's offerings. For many working moms, isolation all too often means thousands of extra hours spent escorting kids and family members to and from out-of-the way places. As for far too many of the inner-city poor, isolating means an inability to reach or even find job opportunities, what has been called the "spatial mismatch" problems. (1998, p. 49).

Cervero said, "The transit village, centered around both suburban and urban transit stations, not only encourages transit ridership, but also embraces goals of increased neighborhood cohesion, public safety, and community revitalization" (1998, p. 16). Peter Calthorpe who worked in Portland, Oregon to create successful mixed-used developments that focused on the emerging transit streetcar system states that in order to create TOD, in addition to other factors, streets have to be pedestrian friendly and infill and redevelopment along the existing neighborhoods in transit corridors have to be encouraged (Dittmar & Ohland, 77). In Peter Calthorpe's book, *The Next American Metropolis: Ecology, Community and the American Dream* (1993), focus is given to creating dense areas with employment and other social activities located along the transit corridor, with residential areas located further away from the transit stations to minimize the noise and air pollution that is associated with transit and transit stations.

Creating TOD in today's market can be a challenge where the mention of higher density can elicit strong negative reactions from the public, developers, and city officials. An even bigger issue is ending practices that emphasize single-use zoning such as low-density residential that the government subsidizes by building expensive utility services and providing Federal Housing Administration loans. On the other hand, billions of dollars have been invested by transit agencies to install heavy rail, light-rail and bus transit systems in metropolitan cities, but only a small percentage of Americans use these systems (Hansen & Giuliano, 2004). According to James M. Daisa, "it seems obvious that in order to maximize the return on the tremendous public investment in transit, we need not only to bring transit to communities but also bring people and jobs to transit by building transit-oriented development that makes transit use a convenient and attractive travel and lifestyle choice" (Dittmar, & Ohland, 2004, p. 114).

While it may seem simple to implement TOD, this concept is much more complicated compared to normal planning practices that are based on Euclidean zoning with different land use types limited to one activity (e.g., residential, commercial, industrial). Furthermore, there is a great deal of data that one can easily access for trip generation and parking demand for this type of land development that follows Euclidean zoning in an suburban context (Dittmar & Ohland, 2004). Since TOD is a relatively new land-use concept, there is little data that can be used to build a model that will explain the demands and impacts of a TOD. Hence, creating TOD is a big financial risk for the cities and developers involved. But there are examples where implementing TOD has been successful such as in Arlington County, Virginia. So what makes a TOD successful? This is a difficult question to answer because when creating TOD, cities and developers must patiently work together since there is no fixed recipe. What was successful in Dallas or Arlington County cannot be replicated in Fort Lauderdale. According to Dittmar (2004) it is important to realize that:

> Contrary to the popular belief, TOD is not about forcing people to live in a particular way. Rather, TOD offers a wider range of housing, mobility, and shopping choices than conventional suburban development (and much urban development). Rather than leaving residents with no other option than to live in a single-family home, shop at an auto-oriented retail center, drive to their workplace, and chauffer their children to activities, transit-oriented developments can offer shopping choices that range from small specialty shops to larger retail outlets, and also allow residents to get around on foot, by bicycle, or transit, which greatly enhances the mobility from a child to a senior. (p.26).

The term TOD should be used to refer to developments that achieve five main goals: location efficiency, rich mix of choices, value capture, place making and resolution of the tension between node and place (Dittmar & Poticha, 2004). Location efficiency refers to the conscious placement of residential areas in proximity to the transit stations so individuals who are economically disadvantaged do not need to own a car or a second car to get to the transit or other amenities. A rich mix of choices means that not only are there multiple modes of transit available, but it is pedestrian/bicyclist friendly, and there are multiple residential choices available such as bungalows, single-family houses, and apartments along with numerous retail and social activities (Dittmar & Ohland, 2004).

Value capture can be used to finance public improvements, such as creating child care facilities or bike rentals in the TOD by using the tax generated by the increased private land values due to the public investments in the transit corridor. Place making refers to making TOD attractive and pedestrian friendly (through design and mixed-use), something that Dittmar claims has been frequently absent in TOD in the US. Lastly, most transit stations serve as a node in the regional transportation network, but in a TOD, it needs to serve both functions, a node and also as a place of interest in a neighborhood. Hence it has to be a place that is accessible for people who arrive at the station by train, bus, car, foot and bike, while also being a place where people can work and shop. Generally a TOD should be a vibrant, pleasant livable space (Dittmar & Poticha, 2004).

Transit-oriented developments can be an effective way of promoting smart growth, but there are also some challenges planners faces during implementation (Niles & Nelson, 1999). One such challenge is the associated cost with TODs. Most times, in order to create a TOD, some form of rail or other fixed-guideway transit is needed since commercial developers are attracted by their permanence (Niles & Nelson, 1999). Furthermore, according to Belzer, TOD sites also require “rezoning and land assembly, which can lead to lengthy-and expensive-acquisition and permitting process” (2007, p. 30). One of the issues that planners face all over the country and also in South Florida is fragmented land that makes land acquisitions difficult. But planners and city officials can help expedite this process by doing some land assembly for the transit agency which will make investing in TOD for developers much more lucrative (Dittmar, 2004).

One of the biggest arguments against TODs is that they aren't affordable since the developments are usually expensive to construct, hence developers aren't really interested in creating and selling affordable housing. Yet in cases such as in San Diego according to Boarnet and Compin (1999), different government agencies including the City of San Diego, Center City Development Corporation (redevelopment authority for downtown San Diego) and San Diego Redevelopment Authority worked together to create low income residential buildings alongside other mixed-use buildings in the TOD.

Cities and developers can spend billions of dollars implementing transit and TOD, but there has to be a demand for them in order to be successful. According to Daisa, several primary components can be used to understand the demand for TODs. They are:

- The demand generated by the transit facility independent of the adjacent land uses; and
- The demand generated by the land uses themselves.

Furthermore, there are also secondary factors that can help define TOD characteristics and relationships. They are:

- Whether land uses are conducive to transit ridership;
- Whether the mix of land uses promotes an internalization of trips;
- The land-use emphasis (e.g., primarily residential or employment) that influences travel patterns;
- The type, scale, interconnectivity, and coverage of the transit system; and

- The location of the TOD in relation to the region (Dittmar, & Ohland, 2004, p. 115).

Giuliano (2004) says, in the US, land use policies are based upon strong property rights where people feel that they have the right to sell their property to developers, regardless if it is industrial, agricultural or environmental. In Florida, this sentiment is very strong for property owners but also for the state and its cities as both depend on growth for funding as sales taxes are very low and residents do not pay income tax. Due to these policies, cities try to grow and compete with each other for industries and residents, and the more they build, the larger their tax base is. Furthermore, the more lax their policies are in terms of where developers can build, the more likely they will be able to grow.

As cities grow, public transit has to travel a greater distance to reach residents, making the system more costly and inefficient. According to the American Road and Transportation Builders Association (2010), the monetary amount spent on roadway construction and maintenance and public transit is:

> It is estimated that federal investment in highway improvements in Fiscal Year (FY) 2009 included $40.7 billion through the core highway program plus a one-time investment of $27.5 billion through the stimulus law, for a total of $68.2 billion. For FY 2010, Congress has appropriated $41.8 billion for the core highway program, an increase of 27 percent. For public transportation, the federal government invested $10.23 billion during FY 2009 through the core transit program plus a one-time supplement of $8.4 billion in the stimulus law, for a total of $18.63 billion. For FY 2010, Congress has enacted $10.73 billion for the core public transportation program, an increase of 4.9 percent. Federal public transportation program funds are used to build and upgrade rail mass transit

systems in major cities and to purchase and upgrade buses and facilities of local transit agencies.

In the past, the federal government funded mostly for highways and roads, with a small percentage dedicated for public transit. This caused the government to inadvertently support sprawl for decades until they realized the staggering associated costs and the heavy fiscal burdens that the sprawling developments placed on the federal and local governments. Today, according to Hanson & Giuliano, there are policies supporting TOD. For example, companies such as Fannie Mae provide “location efficient” mortgages, which give preference to homeowners who are looking for homes within a quarter of a mile from a transit station (2004). Furthermore, according to Cervero and Ferrell, the federal government gives priority to fund projects that “integrate land use developments with TODs and joint development” (Hanson & Giuliano, 2004, p. 225).

If urban infill is to occur, land use and transportation plans and policies have to change, something that can be done by creating TOD that are more mixed-use and dense. The problem with more dense areas is that there are more transportation needs. One of the biggest issues today with the transportation needs in South Florida is that it is one of the most congested regions in the country (Gannett-Fleming, 2006). LOS or level of service looks at the volume of automobiles on roadways to capacity, and LOS A is the best, whereas LOS F is the worst where cars are constantly stopping or have stopped and the volume of the road is at or over capacity. LOS of D or F is a problem especially for air quality since cars emit high levels of carbon monoxide and volatile organic compounds when speeds are lower than 25 MPH (Giuliano & Hansen, 2004). Based on research conducted for the SFECCTA:

> Roadway congestion contributes to the unreliability of travel (variation in travel times) and delays due to incidents and crashes, weather, and other factors that disproportionately impact personal and business travel. Moreover, increased congestion adversely impacts mobility of street transit, such as buses, and ultimately the air quality of the area. (Gannett-Fleming, 2006, p. 14).

One of the problems encountered all over the country is when LOS is poor for corridors, cities and regions attempt to remedy the situation by paving out of congestion. Yet this proves to be unsustainable where the roads are congested again in a matter of time (Burden, 1999). This is what most current policies support, and even if more innovative policies exist, there is little interagency agreement on how to fix these issues in a more sustainable way. So usually, roads are widened or more lanes are added which in turn only makes pedestrians more nervous when walking (Burden, 1999). Furthermore, in order to also improve LOS and air quality, speed limits are raised, perpetuating the problem since it makes the built environment more hostile for pedestrians and bicyclist.

Cities and regions need to understand how policies and practices can make areas unfriendly for pedestrians. For example, areas with sidewalk deficiencies, high speed corridors, and too many parking spaces make pedestrians feel unsafe and these practices should be avoided, especially in a TOD. The problem is that a city may have pedestrian friendly roads that are vibrant and narrow with traffic congestion since the area is popular, but as a result the LOS is poor (Hansen & Giuliano, 2004). So more lanes are added to improve the roadway capacity where cars can travel at faster speeds, improving air quality. This will appease the EPA and other environmental agencies, but inadvertently pedestrian crashes will increase with time due to these “improvements”. Suddenly people do not wish to walk around in the downtown area, and shops that line these roads suffer economically and people live and work further away to avoid these spaces. Exacerbating this issue, the Federal Highway Administration pours billions of dollars into creating and maintaining roads and highways as detailed earlier, making it easier for people to commute to their offices that are no longer located in the downtowns (Hansen & Giuliano, 2004).

Investments have to be made in other areas of transportation such as for the construction of more pedestrian/bicyclist friendly roads and improved public transit systems. But one of the biggest problems for public transit is that density is very low in most areas and Cervero noticed when conducting research that even a small increase of 15% of density can greatly improve transit ridership. Hence policies that integrate higher density and public transit are crucial, and these principles are integrated when developing TOD.

Bae argues in *The Geography of Urban Transportation* that density has a minimal effect on getting people out of their cars and onto transit (Hansen & Giuliano, 2004). But a study conducted by Ingram and Liu concluded that doubling the population density decreases 10% auto use (1999). This percentage may seem insignificant but when considering the millions of vehicles currently on the road, a ten percent decrease would still be substantial (Giuliano & Hansen, 2004). On the other hand, Cervero argues that doubling density increases transit ridership by as much as 60% (1998). Regardless of what the scholars argue, it is clear that policies that measure road capacity have to change especially for TOD so that every time a road is congested, the speed limit isn't raised or more lanes are not added. Rather in a TOD, policies should be created that discourage driving and encourage non-motorized transit and density.

Energy, Air Quality and Transit Oriented Developments

"The design of communities to provide better access with less use of automobiles can result in significant energy savings in the transportation sector and much larger savings in overall societal costs" (Bürer & Goldstein, 2004, pg. 1). The transport sector of the world economy is a major consumer of energy for both developed and developing countries, especially since dependence on oil is only increasing (Giuliano, 2004). Table 2.1 below shows the millions of tons of oil consumed by the different economic sectors worldwide.

Table 2-1. Energy Consumption by sectors (1985 and1995)

		1985		1995	Increment Ratio
	M. Tons of Oil	Share (%)	M. Tons of Oil	Share (%)	95/85
Industry	2,620	40.7	3,057	37.5	1.17
Transport	1,558	24.2	2,161	26.5	1.39
(Road transport)	1,172	18.2	1,704	20.9	1.45
Agriculture	238	3.7	261	3.2	1.1
Commerce and Services	1,062	16.5	1,525	18.7	1.44
Social Welfare	541	8.4	620	7.6	1.15
Other	419	6.5	529	6.5	1.26
Total	6,438	100	8,153	100	1.27

Source: World Resources Institute et al. (1998)

The level of CO^2 produced by transit is directly related to the amount of energy consumed in the US where cars use internal-combustion engine technology (EPA, 2008). While the western world, especially the US, have been major consumers of automobiles and petroleum since the 1920's, as populations, GDP and people's capability to afford cars increase across the globe, especially in Asian countries, there has to be changes in US policies where automobile travel is strongly discouraged and other modes of transit is highly encouraged (Nakamura, 2004).

Since the road transport sector is a major consumer of energy, it is also a major producer of CO^2 emission and other pollutants. According to Nakamura, through calculations it can be assumed that the transport sector produces a little less than 26% of CO^2 worldwide (2004). In the US, we have less than 5% of the world's population, yet we consume 42% of the world's gasoline (Hanson & Giuliano, 2004). Regardless of these staggering statistics, the US has not taken its share of the responsibility for CO^2 emissions as evident in November 2000 when agreements for the Kyoto Protocol was rejected by the president (Nakamura, 2004). But this attitude will have to change in the future as countries such as China and India become more economically powerful and emit more CO^2. According to Robert Cervero, "one study estimates that each U.S. urbanite consumes, on average, ten times as much gasoline as his or her Japanese counterparts, and more than twenty times as much as European city-dwellers" (1998, p. 45). Of course Japan and European countries are much smaller in size with more density. Regardless, "such differences drive up the cost of U.S. goods and products in international markets, undermining the country's international competitiveness" (Cervero, 1998, p.46).

As natural resources related to transit are limited and as demand increases, prices will go up. In South Florida, the Tri-Rail system saw a huge jump in ridership during 2008 when gas prices increased dramatically (SFRTP, 2010). Creating policies and infrastructure that will allow South Floridians to be able to travel without their cars to get to their jobs if and when gas prices increase will prove to be invaluable in the upcoming years. There has been a strong emphasis on producing and using alternative sources of energy but focusing only on policies that support this isn't sustainable. Urban infill along the FEC corridor in the form of TOD can be an effective strategy for not only creating public transit and pedestrian friendly places, but it may help lessen our dependence on automobiles and petroleum (Cervero, 1998). People can live where they work and play, and many times, reach their desired destination by using public transit. Hence, there will be a lesser need for purchasing gas for their cars, and roads will be less congested. All of these factors will improve air quality. Robert Cervero wrote in *The Transit Metropolis:*

> The American Public Transit Association (APTA) claims that, on a per-passenger-kilometer basis (using national averages for vehicle occupancy), riding transit in lieu of driving for a typical work trip will reduce emissions as follows: hydrocarbons and carbon monoxide by 99 percent, and nitrogen oxides by 60 percent if the trip is by electric rail transit (electric rail transit usually gets it energy from coals though it can originate from wind and hydro-power): and hydrocarbons by 90 percent, carbon monoxide by 75 percent, and nitrogen oxides by 12 percent if travel is by diesel bus. (2004, p. 44).

One of the biggest critiques for public transit is that it actually makes air quality worse compared to a no-built option (Dittmar, 2004). This may be true in some regions as in Atlanta, where the transit share is almost negligible with over ninety to ninety-five percent of people choosing to drive as opposed to taking the transit system (Diaz, 2007). But this is the case because transit cannot just be implemented in an area predominated by urban sprawl. It must be done through a combination of practices that promote mixed land uses, support density and all modes of transit (Hansen & Giuliano, 2004).

While there are reserves of petroleum for some decades based on the current demand in the US, it is crucial to remember that as developing countries' demand for oil increases and it becomes a more scarce commodity, we should think along the lines of sustainability and creating TOD can help us do that. As Giuliano states in *Urban Transport and The Environment*, "In order to maintain acceptable levels of mobility while reducing the dependence on petroleum, effective technological innovations are needed, together with changes in infrastructure and lifestyle" (p. 35). The sprawling developments began after World War II, when cars were cheap and plenty and so were people's perception of the amount of petroleum. As we realize that petroleum is a limited resource and more people across the globe can afford cars, it is important that more compact, dense, developments are constructed where we can rely on public transit for most of our transportation needs.

Understanding the Impact of Transit on Transit-Oriented Development

Understanding what makes a successful TOD is critical: high density, good design that addresses the needs of pedestrians/bicyclist, different commercial, residential, and social options, parking maximums rather than minimums, and other planning objectives. But what is also critical to consider is which mode of transit will be utilized for creating the TOD. Rail is exceedingly popular and is the choice for countless cities across the US and the globe. But now, according to Greg Fuhs, the lead author of a study conducted for Maryland's Purple Line Project by World Resource Institutes, BRT is available and it mimics rail transit since it has its own right-of-way in the form of dedicated lanes, signal priority, pre-paid boarding, elevated station platforms, and comfortable vehicles along with well designed and well defined stations (2009).

Many aspects of transit are taken into account when conducting an alternatives analysis such as the capital and maintenance cost of the transit alternative, projected ridership, impacts on air quality, etc. When Fuhs' team conducted the study for Maryland's Purple Line, his team did not consider the "TOD factor" when choosing which transit to implement (2009). This is a common sentiment where studies don't look at which factors will create successful TOD. Or those factors are not important in the final decision making model, even though dense, mixed-use areas like TOD are essential for the success of public transit systems.

Along the FEC, two modes of transit are being considered, heavy rail and BRT. Both of these systems will be "permanent systems" with their own right-of-way and transit stations, which should make developers more comfortable when investing in TOD in South Florida. The following sections will discuss these two technologies to a greater detail.

Bus Rapid Transit or Trains?

The debate about buses vs. trains is common, and this may become more significant for the SFECCTA in the near future as a locally preferred alternative is chosen (Dittmar, 2004). One argument that is frequently given for rail systems according to Polzin and Baltes (2002) is that buses are doing miserably in terms of ridership as it is steadily decreasing in many areas. But what has been found is that whenever a rail system goes into an area, transit ridership increases dramatically (compared to what it was before which in many areas is close to zero). Hence, creating BRT is only an investment that will fail. The opposing argument is based on how to provide the most effective transit that comes with the cheapest price tag. And the most effective transit with the cheapest price tag is BRT. “A BRT option offers not only a chance to provide a richer range of choices with options that have various costs and impacts, but it offers another choice or choices that are eligible for federal funding” (Polzin & Baltes, 2002).

Rail systems have their own right-of-way, allowing the transit to travel more quickly and efficiently, especially since heavy rail systems can travel at significantly higher speeds compared to buses. Rail systems have also been greatly preferred over bus systems despite the fact that the capital cost associated with implementing a rail system is much higher than implementing a bus system (Jarzab, 2002). The capital cost may not be a deterrent factor since the Federal New Starts Program can cover up to 80% of the capital cost when implementing the system, with at least a 20% match in funds from the local governments. Furthermore, according to Polzin & Baltes (2002), BRT many times is still considered the “second-class alternative” to rail. Riding the train to commute has historically been considered more glamorous and whether naturally or through government intervention, TODs around rail stations have occurred in metropolises around the world. Examples of these types of developments around bus stations are not nearly as common. Much of this has to do with the fact that buses did not have their own right-of-way. Now BRT systems have this which means they have a level of permanence, allowing for stations to be developed as an integral part of the TOD with shops and restaurants.

According to Dittmar (2004), the debate is not just about bus vs. trains in any context. “It should be about which technology best will serve the community’s vision of how it wants to grow. So after density, what matters is: frequency, speed, regional context, capacity, attracting development" (p. 37). In order to move bus or rail passengers, it is crucial that the passengers can travel with speed and reliability. Exclusive rights-of-way (ROW) and/or traffic priority signals help improve the speed and reliability. According to Jarzab (2002):

> Separating transit service from the general traffic stream has always been the preferred solution for maintaining speed and schedule adherence. Unfortunately, physical space and financial capital are rarely available to take full advantage of the benefits of exclusive rights-of-way. When both are in equal abundance, the technical choice between buses and rail is often a matter of deciding whether the travel corridor warrants high capacity at the expense of distribution flexibility and/or whether sizable segments of project right-of-way can provide transit simultaneously. (p. 42).

If the corridor is at high capacity with high population density, then heavy rail is suitable and if not, then BRT is the more appropriate choice. There are many more differences between these two systems, including their impact on land development patterns. More about these concepts will be discussed in the upcoming sections and chapters.

Bus Rapid Transit (BRT)

"A key characteristic of BRT is the prospect that it can provide a lower-cost method of providing better performing public transit service that is both able to retain current and attract new customers as well as garner political and taxpayer support" (Polzin & Baltes, 2002, p. 49). The price tag associated with building a BRT system makes this mode of transit lucrative. When comparing the no-built option to the built option which very commonly is the rail system as seen in the South Florida East Coast

Corridor Transit Analysis, the BRT system offers this unique opportunity where the capital cost falls between these two options. Regardless of the lesser price tag, the gargantuan capital cost associated with building any of these transit systems makes it impossible for local governments to implement them without the help of the Federal New Starts Program. According to the Federal Transit Administration:

> Projects eligible for New Starts (49 USC §5309) funding include any fixed guideway system which utilizes and occupies a separate right-of-way, or rail line, for the exclusive use of mass transportation and other high occupancy vehicles, or uses a fixed centenary system and a right-of-way usable by other forms of transportation. This includes, but is not limited to, rapid rail, light rail, commuter rail, automated guideway transit, people movers, and exclusive facilities for buses (such as bus rapid transit) and other high occupancy vehicles. (2001).

As explained by Hansen and Giuliano, the concept of BRT is based on the fact that it has its own rights-of-way or a fixed guideway system. Furthermore, “the cost, time frame for implementation, geographic coverage, and ridership for BRT can be significantly different than for other alternatives under consideration” (Polzin & Baltes, 2002, p. 49).

Rail systems must function along a high capacity corridor with high density in order to be successful. BRT will also be successful in a high capacity corridor with high density that has its own right-of-way, but unlike rail, BRT is not confined to that right-of-way (Jarzab, 2002). If needed, BRT can operate along other routes, giving it an element of flexibility that is missing in the rail system. If an area has dispersed land development patterns and density, then this makes BRT the more attractive alternative.

Rail systems will not be very successful if the area isn't dense and the system is dependent on feeder buses to bring transit riders to the rail system. Multiple-seat ride is something passengers strongly dislike, and rail systems will be dependent on these feeder buses to make them successful. BRT has the flexibility of being a feeder bus and starting its route away from the main corridor; it can then utilize its fixed-route and this will prevent the multiple-seat ride that is associated with rail systems in low-density areas (Jarzab, 2002).

Jarzab refers to "sizable segments of project right-of-way" and the reason why this is a key element is because when building rail systems, it must be done to offer continuous service (2002). Service cannot just be provided for two miles, then stop because of time or financial constraints. It must be done in a way that makes sense to the transit riders. For example in Ottawa, a 19-mile BRT transit way was implemented in stages from the year 1978 to 1996. This BRT transit way was actually constructed in rail rights-of-way, similar to the FEC rail right-of-way and provisions for a potential future conversion of this BRT transit system to a rail system was made (Jarzab, p.49). A transportation project has to garner public support to show that it can be successful before the government is willing to make large financial investments. Furthermore, "many suburban-edge cities exceed the aggregate employment base of many big city CBDs but do not currently have the focus and density to make rail based rapid transit a cost-effective investment" (Jarzab, pg. 28, 2002). If there is a lack of population and employment density in an area, then heavy rail should not be implemented in that area.

It is argued that transit-oriented developments cannot be created without rail. As discussed earlier and explained by Robert Cervero, developers take a risk when building transit-oriented developments rather than traditional single-use developments. The rail offers these developers a level of confidence because of the sense of permanence that rails provide. In Ottawa and Vancouver, transit-oriented developments are being built around BRT systems and they have been successful (Dittmar, 2004).

It is essential that in order for a transit-oriented development to be successful, it must be an attractive place to live, work and play. It is also imperative that the transportation system be attractive. Buses are commonly thought of as being unattractive and second-class compared to rail systems. But BRT can look and act like rail systems, especially light rail systems. Hansen and Giuliano quote U.S. General Accounting Office about what additional features will make BRT much more attractive and modern. They are:

> (1) traffic signal priority, (2) prepaid or electronic fare passes, (3) low-floor vehicles or platform-level boarding with multi-door entry and exit, (4) increased distance between stops, (5) improved stations and shelters, (6) cleaner, quieter, and more attractive vehicles and (7) Intelligent transportation System (ITS) technology to optimize bus scheduling and provide passengers with real time information. (2004, p. 230).

Also the importance of marketing this system should not be ignored. According to Jarzab, the "purpose of marketing is to distinguish BRT from conventional bus service. The marketing for and branding of BRT appears to influence how the public, the press, and elected officials will respond to the service. In addition, the size and appearance does matter for BRT" (2002, p. 38). By showing how the BRT system greatly differs from the traditional buses and the fact that BRT is very similar to rail systems, transit agencies, local officials, and residents are more likely to seriously consider this system.

In order for transit-oriented developments to be successful, passengers must be willing to utilize the transit systems. Different studies show different conclusions but according to Vukan R. Vuchic, “passenger attraction of the two modes is often discussed. Evidence from many cities shows that on a given general alignment, rail transit attracts considerably more passengers than buses. Examples are the substantial ridership increases when rail transit replaced buses in a number of cities, such as Calgary, St. Louis, Denver, and Dallas” (p. 90, 2002). But these studies compare rail with normal city buses, not modern buses with their own right-of-way. There are no examples that could be found that shows what happens in terms of passenger ridership when BRT systems are changed to rail systems. Hence, most scholars are hesitant to come to a definite conclusion about this topic.

Buses have replaced the original rail systems in cities decades before, and they have had a negative image since they can be loud and dirty, with high emissions. If we compare rail to the old diesel buses, then this image is true. It is important when implementing a bus rapid system that attention is given to make the system efficient, comfortable and aesthetically pleasing. The next section of this literature review will look at the impacts of heavy rail on TOD and the two types of heavy rail, the Push-Pull Locomotive and Diesel Multiple Units.

Rail: Push-Pull Locomotive and Diesel Multiple Units

When implementing a rail system, whether it is light rail or heavy rail, the choice must be the mode that most citizens and local officials prefer. There is a strong desire to travel in rail transit systems similar to the Subway in New York City, the Metro in Washington D.C., or the L in Chicago (Jarzab, 2002). Along the Florida East Coast Corridor, there are two rail alternatives being considered, the Diesel Push-Pull Locomotive and the Diesel Multiple Unit (DMU). These two types of heavy rail system are similar, with matching carrying capacities and maximum speed.

Rail makes investors and developers feel more confident when financing and building TOD (Dittmar, 2004). For investors such as banks that will lend to the developers, a level of commitment to transit service serves to create a level of confidence that what they are investing in, transit-oriented developments, will not simply disappear. According to Jarzab, the “permanence of rail right-of-way and station development is widely regarded as an irreversible public commitment to transit service capable of attracting private sector investment supportive of community development goals and objectives” (p. 36, 2002). In order to finance TOD, along with strong community planning and support, developers must “do everything possible to make them recognizable to investors and to minimize uncertainty” (Dittmar, 2004, p. 84). Though it is possible to convince investors to invest in TOD that are served by BRT systems, the number of examples where this is the case are too few to lower the uncertainty that is associated with it. So when attracting investors and developers to create TODs, without governmental intervention, rail truly triumphs over BRT systems.

Exclusive right-of-way is usually not available due to the “prevailing political and financial climate, where exclusive guide-way operations are often out of reach of most transit agencies, even for those corridors with the heavy transit demands” (Jarzab, p. 37, 2002). When exclusive right-of-way is there, it is best to utilize that exclusive right-of-way for rail operations rather than BRT. (Jarzab, 2002). But it is also important to remember that just because the right-of-way is available does not mean that it should be utilized since density plays a much larger role for creating a successful heavy rail transit system (Dittmar, 2004). This was the case as discussed earlier in Ottawa. Even though the city had exclusive right-of-way, they used the corridor for BRT rather than rail. If the density is missing, then the transit ridership will be too low, forcing the system to cut its fiscal budget. It then becomes part of positive feedback loop where once the budget is cut, service decreases, ridership decreases and so on.

When creating TODs, it is essential that the transit system has the capability to change land use patterns to support the TOD along the corridor. Although scholars argue that BRT can influence the area to become denser, the overall results seem inconclusive. Vuchic argues that, “impacts on land-use development along the line are generally related to the permanence and image of transit system facilities” and rail has shown to have a positive impact to create more dense developments adjacent to the corridor (2002, p. 88).

Heavy rail also has a higher capacity and can travel at higher speeds compared to BRT systems. Every unit of Diesel Multiple Unit has the capacity of carrying 90 to 100 passengers. The DMU railcar is also flexible since each rail car has a locomotive. Hence four or five DMU railcars can operate together, carrying 360-500 passengers during peak hours, and during off-peak hours, only one or two cars can be utilized carrying anywhere from 90 to 200 passengers. Diesel Push-Pull does not have this flexibility, but each railcar carries approximately 100 passengers. BRT comparatively has the capability of carrying 78 passengers at full capacity. Another aspect of the

DMU that makes it superior compared to the Push-Pull locomotive is the fact that it has superior breaking and accelerating capabilities.

TODs have become a popular tool that cities and regions utilize to promote smart growth and public transit. A TOD can be defined as mixed-use developments where office spaces coexist with adequate residential and other commercial activities (Dittmar, 2004). Furthermore, in these TODs, public transit can truly reduce/eliminate the need for automobiles. In this literature review, TOD and its implications on air quality and energy along with the transit options, BRT and heavy rail were discussed. In the upcoming chapter, the methodology of how to evaluate whether BRT or heavy rail is the more appropriate transit for creating TODs in South Florida will be addressed.

CHAPTER 3
METHODOLOGY

In this thesis, it is being examined which mode of transit, BRT or rail (Diesel Push-Pull and Diesel Multiple Unit) could help create transit-oriented developments (TOD). This study evaluates the decisions being made in South Florida with respect to these technologies for transit use by doing a case study of the decision to provide transit service on the FEC line and case studies throughout North America. First, a case study of the demand to live in South Florida and the potential of creating TOD was conducted. Then case studies were based on the two modes of transit: BRT and trains. Examples of TOD built around BRT systems are not common, especially in the United States; hence a case study was conducted for Ottawa, Canada in addition to the city of Pittsburgh, Pennsylvania.

Case studies of Pleasant Hill, California and Arlington County, Virginia were conducted where TOD are built around heavy rail systems to determine which transit characteristics in rail make TOD successful. Atlanta, Georgia also served as a case study where TOD in this city have not been as successful compared to TODs in the four other areas and this gave insight into what policies and actions are detrimental for creating successful TOD. Based on these case studies, the characteristics of transit that are critical for creating successful TOD were applied to secondary data collected from South Florida East Coast Corridor Transit Analysis.

To gain an understanding of the population currently living within a quarter to half mile of the Florida's East Coast (FEC) corridor in Palm Beach, Broward and Miami-Dade County, Geographic Information System (GIS) data from United States Census Bureau and the mapping program, ArcGIS was utilized. Furthermore, GIS data was collected from the United States Department of Transportation (DOT) to obtain information about the FEC corridor. Based on this information, an understanding of what the current demand to live along this corridor was gained which served as a predictor of how successful TOD and public transit will be in this region. In addition, population and employment density maps were obtained from the South Florida East Coast Corridor Transit Analysis and these density maps were analyzed. In terms of population and density, as discussed in the literature review, high density linear corridors are best served by rail systems whereas in less dense corridors, BRT will be a more appropriate transit choice.

There were data limitations for this methodology that should be addressed. Data utilized for this research relied heavily on US Census data from the year 2000. Data from the 2010 US Census would have provided a more accurate understanding about the population and density in South Florida, Arlington County, Pittsburgh, Atlanta, and Pleasant Hill.

CHAPTER 4
CASE STUDIES

Overview of the FEC Corridor

The Florida East Corridor (FEC) is a rail corridor that begins from the city of Jacksonville, running parallel to the Atlantic coast, and it concludes in the city of Miami for a total length of 351 miles. It is primarily a freight corridor with some passenger rail service being currently provided by Amtrak. The portion of the FEC corridor being studied for this transit analysis is approximately 85 miles long and it extends from the town of Tequesta in Palm Beach County to the city of Miami. It is estimated that the average trip length along the corridor will be 3 to 17 miles and service along the FEC corridor will be local with more frequent stops compared to Tri-Rail (Gannett-Fleming, 2006). Ridership along the FEC corridor is projected to vary based on the different alternatives, but it is estimated that there will be a reduction of 161,407,700 vehicle miles traveled yearly with about 60,000 riders projected daily (Gannett-Fleming, 2006). During the first phase of the SFECCTA (South Florida East Coast Corridor Transit Analysis), multiple modes of transit were being considered. The study is currently in Phase II, and three modes of transit were redefined as alternatives: Bus Rapid Transit (BRT), Integrated Rail "DMU", and Integrated Rail "Push-Pull". Below, there is a description of the BRT, and the two types of heavy rail being considered for this corridor, the Diesel Push-Pull and the Diesel Multiple Unit railcars.

Description of the Alternatives in Context of SFECCTA

Bus Rapid Transit (BRT)

The bus rapid transit system will be utilized along the FEC corridor with a new right-of-way constructed adjacent to the present freight track to facilitate the BRT. The corridor is currently 100 feet wide and 50 feet of that corridor will be utilized to construct the new BRT right-of-way. The length of the FEC corridor will be divided into four segments and at the four connecting stations between the four segments, connections to Tri-Rail will also be provided. There will be 52 allocated stations for this alternative (Gannett-Fleming, 2010). Since Tri-Rail provides service approximately every 4 to 6 miles, it will serve as a transit system that takes commuters to their destinations at a higher speed (45 mph compared to 30 mph for FEC service). BRT will provide local service, with frequent transit stations (every 1 to 2 miles) and at the four connecting stations, passengers with one ticket can seamlessly transfer from the FEC to the Tri-Rail system. Hence, the commuter rail service provided by Tri-Rail and BRT local system provided by FEC, will be an integrated system. Two peak-hour express routes will be utilized to supplement all other routes. The capital cost for implementing this system is about $6 to $8 million per vehicle and the annual operating cost per revenue mile will also be $6 to $8 million. Furthermore, in terms of energy consumption, BRT consumes 0.36 gallons of biodiesel per mile (Gannett-Fleming, 2006).

According to Gannett-Fleming, there is adequate right-of-way available along the FEC corridor to build dedicated guideway for the BRT system parallel to the rail tracks that the freight trains are currently using. The Federal Railroad Administration (FRA) does not dictate how a BRT system can be implemented along the current freight track system. The BRT stations will provide some physical barriers between the BRT guideway and the rail tracks when the freight trains utilize them in order to provide a safe and secure service to the passengers of the BRT system. The BRT stations will be built at the same height as the vehicles so passengers can easily enter and exit the BRT, minimizing the waiting time at transit stations. (Gannett-Fleming, 2006)

Diesel Multiple Units (DMU)

This alternative will provide integration of the Tri-Rail commuter rail system, with a new express and local rail service along the FEC corridor (Gannett-Fleming, 2010). DMU will be utilized along the whole length of the FEC corridor. Majority of the railcars that are utilized by Tri-Rail are the Push-Pull locomotive railcars but there are also a few DMU available. This alternative will allow for two connections, one in West Palm Beach and another in Pompano Beach between Tri-Rail and the FEC corridor. In these two stations, passengers can seamlessly go from one rail service to another based on their commuting needs. DMU will travel at a lower speed of 30 mph compared to Tri-Rail that will provide service at a higher speed of 45 mph. There will also be 52 transit stations available for this alternative. The capital cost for implementing this system is approximately $5 to $9 million per vehicle if the system uses the rail tracks that the freight trains are currently utilizing. If additional tracks are added, the cost will be substantially higher and the annual operating cost per revenue mile for heavy rail will be $11 to $13 million. Furthermore, in terms of energy consumption, DMU consumes 0.5 - 0.67 gallons of biodiesel per mile (Gannett-Fleming, 2006).

Initially for the FEC corridor, the construction of additional tracks was being considered. There is now discussion to use the existing tracks that freight trains are utilizing, with future coordination efforts from the freight and transit systems in an effort to save capital cost and to make road crossings easier (Gannett-Fleming, 2009). If additional tracks are built, there are strict Federal Railroad Administration (FRA) guidelines that must be followed such as the distance between the two rail systems and the type of grade separation to ensure passengers' safety. This system will also pose some design issues if this is the locally preferred alternative since two sets of rail tracks can make road crossings more difficult for pedestrians, bicyclists, and drivers (Gannett-Fleming, 2009).

Diesel Push-Pull

This alternative will provide identical service to the Integrated DMU rail alternative. The only exception will be that Push-Pull locomotive cars will exclusively be utilized along the FEC corridor. There will also be integration between the Diesel Push-Pull rail and Tri-Rail services along the FEC corridor. The integrated system will be identical to the DMU service; there will be two connections, one in West Palm Beach and another in Pompano Beach between Tri-Rail and the FEC corridor. In these two stations, passengers can seamlessly go from one rail service to another based on their commuting needs. Diesel Push-Pull will travel at a lower speed of 30 mph compared to Tri-Rail that will provide service at a higher speed of 45 mph. Also, the capital cost for implementing this system is approximately $5 to $9 million per vehicle. If additional tracks are added, the cost will be substantially higher and the annual operating cost per revenue mile for heavy rail will be $11 to $13 million. In terms of energy consumption, Push-Pull consumes 2.18 gallons of biodiesel per mile (Gannett-Fleming, 2006). Finally, like DMU, if Diesel Push-Pull is implemented, additional rail tracks may not be constructed in an effort to save capital cost and to make road crossings easier for pedestrians, bicyclists and drivers.

The Demand to Live and Work in South Florida

According to Hansen and Cervero, there must be some demand to live and work in an area for a TOD to be successful.   So what is the potential and demand for creating TOD in South Florida? In terms of office space, Robert E. Lang, author of *Beyond the Edge City* examined the role of central business districts in South Florida. This study is pertinent to the FEC corridor because the areas studied here are transversed by the rail corridor. He compared thirteen major regions across the USA from 1987 to 2002, and based on his findings, he concluded that "only 13 percent of South Florida's office space is located in its central business district (CBD), compared to a median of nearly 30 percent for all 13 markets" which includes the CBD of San Francisco, New York City and Chicago (2003).

Edge city is any area that is concentrated with office space that exceeds five million square feet and is less than 30 years old. In the South Florida region, the two major edge cities are Boca Raton and areas around Miami-Dade International Airport. In this study, it was also found that in addition to the CBDs and edge cities where 33% of office buildings are located, there are also edgeless cities or areas of office sprawl. Edgeless cities or cities that resulted from sprawling developments, are found most frequently in Miami, Fort Lauderdale and other South Florida cities, where 66% of offices are located (Lang, 2003). For perspective, Philadelphia has the second highest amount of offices in edgeless cities with 54% of its offices scattered around the CBD (Lang, 2003). Overall, looking at office spaces, in the CBD (not edge cities) of South Florida, only 13.1% of offices are located there (Lang, 2003). Comparing South Florida to two cities that have created TOD in the CBD areas, Atlanta and San Francisco, Atlanta has 23.5% of its offices located in the CBD, and San Francisco has 33.9% of its offices located in the CBD.

One of the major problems in South Florida that Robert Lang states is that, “because most edgeless city growth occurs outside central cities, it pulls resources from the regional core. Research has shown that these metropolitan peripheries have received far more investment than the center and the inner ring of suburbs” (p.12). So in essence, the whole area is paying financing sprawl. There is disinvestment in the core cities that line the coast as in South Florida, areas that are considered more attractive and expensive, and the cities lose their tax revenue.

Luckily with the federally mandated growth boundaries placed in South Florida, redevelopment infill will most probably occur in the core cities instead of more wetlands being drained for new developments. Though South Florida has the most office sprawl in the nation compared to other major metropolitan regions, policies that supported the sprawl have changed. With the new policies that South Florida has adopted and is in the process of adopting, there will be a shift where more investments will be made in the core cities that line the coast. Coastal properties as seen worldwide are generally more expensive, hence they generate more capital for the local government (Hansen & Giuliano, 2004)

As James Daisa (2004) said, there must be some demand for the land in order for TOD to be successful. There is demand to live and work in the coastal areas of South Florida, near the CBD, although as seen in Robert Lang’s study, it is lower compared to other metropolitan areas in the United States. The government can implement policies that increase the demand, which in this case is in the form of an urban growth boundary. When looking at the demand to reside in the study area, it was found that Palm Beach, Broward and Miami Dade County have a high population compared to the majority of other counties in Florida. Based on population estimates from 2008 from the Bureau of Economic and Business Research (BEBR), other than the three counties that are being studied in this research, only Orange and Hillsborough County passed the one million population threshold. Table 4-1 below shows the current population and the projected population growth of the three counties in South Florida until the year 2035. In this population projection, only adjustments were made that looked at institutional populations such as university students and prison inmates. No adjustments were made in Palm Beach, Broward and Miami-Dade County; the large population of “snow birds” was not accounted for which BEBR estimates to be about 350,000 people (1997). Based on this data and comparing this information to the population projections in other parts of Florida, it is evident that this region is one of the most attractive regions to live in Florida. In addition to this information, the demand to live east of the FEC corridor is high since the corridor is located within a few miles of the Atlantic Intracoastal Waterway. The desire to own and/or live near coastal property is strong, where prices for these parcels are usually much higher than land located further away from the coast (Blakely and Bradshaw, 2002). Regardless, density is the key for creating TODs along the FEC corridor (Cervero, 1998). Based on density and other factors, the question, will BRT or heavy rail help create successful TOD along the FEC corridor will be answered.

Table 4-1. Population Projections for South Florida Counties

County	2010	2015	2020	2025	2030	2035
Palm Beach						
Low	1,234,300	1,241,100	1,252,000	1,149,600	1,156,400	1,150,300
Mid	1,285,700	1,346,000	1,420,400	1,433,200	1,535,000	1,630,800
High	1,337,100	1,457,000	1,593,400	1,724,400	1,927,400	2,136,300
Broward						
Low	1,693,200	1,682,000	1,671,200	1,655,800	1,635,400	1,610,400
Mid	1,745,600	1,787,200	1,835,000	1,880,000	1,921,200	1,958,900
High	1,797,900	1,896,700	2,001,800	2,107,400	2,212,600	2,317,400
Miami-Dade						
Low	2,406,300	2,411,400	2,417,800	2,416,500	2,406,800	2,389,200
Mid	2,480,800	2,561,300	2,654,000	2,743,000	2,825,900	2,903,500
High	2,555,200	2,719,300	2,896,000	2,896,000	3,256,200	3,438,100

Source: Bureau of Economic and Business Research (2009)

If people are not interested in living in an area, then the possibility of creating a TOD is very slim. So what does this mean for South Florida, more specifically Palm Beach, Broward and Miami-Dade County where the proposed transit will provide service? What is the demand for people to live or work there? Table 4-2 below shows the list of the top 25 most populated cities in Florida based on the 2000 census and the bolded cities are the cities within the three counties of South Florida that will be directly or indirectly impacted by future transit along the FEC corridor.

According to Table 4-2, out of the 25 most populated cities in Florida, 14 cities fall into one of the three counties and either is transversed by the FEC or lies to its west. Cities such as Davie, Pembroke Pines, Sunrise, Plantation, Davie, Hialeah and Miramar are located west of the counties due to decades of policies that allowed for westward expansion, despite the Everglades National Park. These areas or the people living in these areas will not be impacted by implementing a local transit system in the FEC corridor at this time**.**

Table 4-2: 25 Most Populated Cities in Florida

1. Jacksonville - 736,000	14. Gainesville - 95,000
2. Miami - 362,000	15. Port St. Lucie - 89,000
3. Tampa - 303,000	16. Miami Beach - 88,000
4. St. Petersburg - 248,000	17. Sunrise - 86,000
5. Hialeah - 226,000	18. Plantation - 83,000
6. Orlando - 186,000	19. West Palm Beach - 82,000
7. Ft. Lauderdale - 152,000	20. Palm Bay - 79,000
8. Tallahassee - 151,000	21. Lakeland - 78,000
9. Hollywood - 139,000	22. Pompano Beach - 78,000
10. Pembroke Pines - 137,000	23. Davie - 76,000
11. Coral Springs - 118,000	24. Boca Raton - 75,000
12. Clearwater - 109,000	25. Miramar - 73,000
13. Cape Coral - 102,000	

Source: State Department of Florida & the US Census Bureau (2000)

In addition to the population who reside in Florida yearlong, many people come to Florida during the winter months where they can relax in their large private properties, something that is usually more expensive in other regions of the US such as in the Northeast. According to University of Florida's Bureau of Economic and Business Research (BEBR), during the month of January, about 1 million snowbirds come to Florida, with about 35% of these people traveling to Southeast Florida (1997). Furthermore, according to similar research, since the 1960s, approximately 1000 people moved everyday to this state. As stated earlier, some people come to Florida to escape the temperature and/or the density of other regions where the cost of living is usually relatively higher, and so Floridian cities cater to their demands. But in an attempt to stop this pattern of growth in South Florida, a federally mandated urban growth boundary (UGB) was established which prevented greenfield developments west of Interstate 95 and focused on redeveloping brownfield sites in an attempt to lower infrastructure costs and to preserve what was left of the Everglades National Park (Lang, 2004). As the South Florida Regional Planning Council states “The cost of inefficient, sprawling development has an impact on all taxpayers, businesses, suburban and urban residents, agriculture and the natural environment. It uses up vacant land more quickly, limiting the ability to preserve environmentally sensitive lands, prime agricultural land, and water resources” (1998).

In order to limit the costs associated with sprawl in addition to the detrimental environmental impacts such as poor air quality, interest was taken in redeveloping downtowns and other developments that dated back to Henry Flagler. The South Florida Regional Planning Council took initiative to develop a master plan with other agencies that coordinated these anti-sprawl efforts, and this master plan was appropriately called Eastward Ho! The SFECCTA was initiated due to policies in the Eastward Ho since it brings back development east of Interstate 95, and policies like these are crucial when developing TOD. As Dittmar states, “TOD cannot be created along a single parcel. Furthermore, when market forces alone are not strong enough to support good TOD, then the local government becomes an even more critical actor. Most successful TOD projects are those that involve a partnership between public and private sector” (2004, p.49). This is the case in Florida where there was rapid growth, and the housing market was very strong in the first half of this decade with developments occurring at low density. But once the housing bubble burst, Miami for example was one of the top cities in the US where the real estate values took a nosedive, leaving many single-family houses vacant.

This case study focused on population, and the demand to live in South Florida, because without population density, transit systems cannot be successful and without demand, TOD cannot be successful. The following case studies will focus on the areas that have built TOD around their transit systems and they will help identify the transit characteristics that are necessary for successful TOD.

Pittsburgh, Pennsylvania

The city of Pittsburgh has a population of 335,000 people, with a population density of 6,000 people/ square mile (US Census, 2000). Though the concept of the BRT system is almost unknown to most Americans, there are some examples around the country (Judy, 2007). In 1997, the city of Pittsburgh began to use this transit system, though to a much smaller scale compared to today. Incrementally, the BRT system has been increased and currently, it provides 19 miles of service, including in the downtown area (Cervero, 1998). Pittsburgh uses an integrated system with light rail, but as the BRT system proved to be more successful compared to light rail, it has been increased incrementally. There are reasons for its success. For example, some of the key features of Pittsburgh's BRT system are the high-quality stations that are comparable to any rail station and efficient transit service that adheres to its schedule in respect to time and frequency (Judy, 2006). Furthermore, it has many features such as pre-board payment which makes this service more efficient for passengers and BRT operators, and clean vehicle technology with low emissions (Wright, 2006). The vehicles also produce less noise and vibrations, making it more residential friendly (Wright, 2006).

The BRT system has a combination of stations that have parking facilities and stations that don't. Parking facilities are located at stations furthest away from the downtown area, allowing passengers who commute great distances, the ability to park and ride to work (Cervero, 1998). The stations that do not have parking station are closer to the downtown areas and these areas are considered to be more pedestrian-friendly locations where residential areas are located. Pittsburgh used four policies for creating its successful TOD: create pedestrian-friendly areas, reduce automobile usage by having parking maximums rather than minimums, design the city around its transit, and have compact mixed-use land uses that are supportive of transit (Judy, 2006).

The BRT system in Pittsburgh has an impact on land development patterns and values (Wohlwill, 2004). Just along one section of the BRT systems, the East Busway section, 54 developments have occurred between the years of 1983 to 1996 and they have a total market value of $302 million (Wohlwill, 2004). Based on data from 1996, it is estimated that another $203 million worth of development has occurred along this corridor and in the year 2004, additional developments were constructed for a total value of $300 million (Wohlwill, 2004). Developments increased dramatically when the BRT's right-of-way was rebuilt, helping to improve the aesthetic aspect of the system (Tann, 2009).

Ridership for the East Busway section during week days ranges from 25,000 to 28,000 passengers and along the West and South Sections, 9,000 passengers utilize the system (Tann, 2009). The total ridership for this BRT system ranges from 34,000 to 37,000 passengers. The light rail system is 25 miles long, with lower ridership compared to the BRT system (Tann, 2009). Tann's study which was conducted for the Federal Transit Agency looked at the impact of prices of single family homes located along the east section of the BRT system. It was found that a "property 1,000 feet away from a station is valued approximately $9,745 less than a property 100 feet away" from the station (Tann, 2009, p. 75). To conclude, it was found that there were strong land use impacts due to BRT, with developers competing to develop on land adjacent to the BRT system (Tann, 2009).

Ottawa, Canada

Successful examples of the BRT system are much more common in Canada than in America (Dittmar, 2004). Numerous cities in Canada use the BRT system including cities such as Vancouver but Ottawa is the best example of how BRT systems can contribute to successful TODs. One of the most important reasons why BRT and TOD are so successful in Ottawa is because the city places strict policies that make it difficult for the residents to use automobiles (Currie, 2006). The public has easy access to the transit while local governmental policies ensure that transit supportive land uses are adjacent to the transit corridors. Investments to create pedestrian-friendly areas have been pursued with pedestrian-bridges being a common sight (Judy, 2007).

The city of Ottawa has a population of 774,000 people, with a population density of 771 people/ square mile (Canada Census, 2001). This population density takes into account Ottawa city and its greater area, where 80% of the land is rural (Judy, 2007). In terms of ridership, 240,000 people utilize this transit system on a daily basis (Currie, 2006). Parking facilities are limited, with only 5,340 parking spaces available for automobiles along the transit corridor. The BRT system also has a very short headway, especially during peak hours where the headway ranges from 20 seconds to one minute (Currie, 2006).

The BRT system in Ottawa is 19-miles long, is composed of 38 stations and was built in 1983. Originally, rail was being considered for this area, but due to its flexibility with the capability of buses to leave the guideway, BRT was the technology chosen (Currie, 2006). The TOD and BRT system in Ottawa also became successful because BRT produces less air pollutants and causes less vibration compared to heavy rail (Judy, 2007). The buses are also low-floored, are aesthetically pleasing, and the stations for the BRT are well developed with a rich variety of commercial, residential and other activities. Unlike Pittsburgh, there isn't a pre-paid boarding system (Currie, 2007).

The BRT system is very popular in Ottawa, partly due to strict policies such as high parking rates in the CBD that discourage automobiles usage especially during peak-hours. Furthermore, the BRT reaches areas with low density that rail cannot have access to since it can utilize regular roads. One of the issues that this system is now facing is that the demand for this transit is such that serious considerations are being made to convert this BRT system to a rail system (Judy, 2007).

Arlington County, Virginia

According to US Census data, there are 189,453 people living in Arlington County with a population density of 7,323 people per square mile in the county's 26 square mile area (2000). In 1979, the Washington Metropolitan Transit Agency (WMATA) opened the Rosslyn-Ballston corridor, a 96 miles long heavy rail system (Cervero, 2004). Before, this area was a low-density commercial area that was in desperate need for redevelopment (Dittmar, 2004). Building consensus between different governmental agencies, TOD was chosen as the tool that would redevelop this area (Dittmar, 2004). Due to the consensus that the agencies were able to reach with limited controversy, developers were attracted to this area despite the fact that they were required to pay for major public infrastructure improvements, even during recessions in the economy (Dittmar, 2004).

Today, this three mile corridor and its stations have the highest ridership compared to other stations in the entire rail system. This case study is an example of a transit system and TOD where they both developed simultaneously (Dittmar, 2004). Through efforts by the government, TOD were planned to be built around stations with high-density and as the distance from the transit station increased, the density decreased (Dittmar, 2004).

Transit ridership for this rail system is also very high where during the weekdays, about 40,000 passengers use this three-mile corridor (Cervero, 2002). According to U.S. Census 2000 data, over 32,000 people over the age of sixteen live there with a total number of 19,000 households and each household on average has on average one car (Cervero, 2002). Furthermore, the rail system has had a huge impact on the values of properties adjacent to this system where in the last 10 years, the prices of properties increased by 81% (Cervero, 2002).

The rail system has been successful in creating transit-oriented developments in this area (Cervero, 2002). When this transit system was built, it was built to provide public transit to the nation’s capital and its surrounding areas. This system is also integrated by major transit hubs where over 20,000 passengers use the bus system in the Rosslyn and Ballston stations (Leach, 2004). Developers were attracted to this system due to its permanence and also because the government was able to reach a consensus when constructing it. Efforts by the government to redevelop this area along with promoting the importance of creating walkable neighborhoods with good design was not overlooked. Through creating policies similar to Ottawa, developments were centered around the stations and public participation and affordable housing was included (Leach, 2004).

Pleasant-Hill, California

Pleasant Hill is located 27 miles from San Francisco and Contra Costa Centre Transit Village is a TOD in this town that utilizes Bay Area Rapid Transit's Heavy Rail System. This city has a population of 32,700 people with a density of 4,624 people per square mile (US Census, 2000). Although the Pleasant Hill station was built in early 1970s, this TOD is relatively new (Lund & Cervero, 2004). It has over 2.8 million square feet of office space area with over 2,800 residential units located within 1 mile of the station. The Contra Costa County Redevelopment Agency successfully used TOD as a tool to redevelop this area (Lund & Cervero, 2004).

Major employers are located there due to the availability of office and retail space. The most important factor that has caused investors to develop in this area is due to the Bay Area Rapid Transit's (BART) heavy rail system which gives investors and developers a sense of permanence. The BART system isn't new, and the Pleasant Hill station is about forty years old. Through careful efforts and with public participation, the TOD around the Pleasant Hill station is becoming increasingly successful. This isn't the only example of how the BART system is creating TODs. There have been continuous efforts made by this transit agency to create TOD in many areas and stations, and the common themes for these stations are TOD and urban infill (Lund & Cervero, 2004).

According to a study, it was found that "for every meter a house was closer to the nearest BART station in Contra Costa County, the sales prices increased by $1.96.

Furthermore, a house that was immediately adjacent to the BART station would sell for 38% more than an identical house 35 kilometers away from the BART station" (Diaz, 2007, p. 3). There were some negative impacts that were found with the heavy rail system such as noise pollution along with the vibrations that heavy rail produces. Regardless, the benefits of living close to a transit station in an area where there is a high demand outweighed these negative impacts (Diaz, 2007).

Atlanta, Georgia

Atlanta is a major, sprawling city that has a heavy rail transit system. The city has a population of 416,474 people with a density of 3,155 people per square mile (US Census, 2000). The history of this rail transit system and the transit agency, the Metropolitan Atlanta Rapid Transit Authority (MARTA) was fraught with problems such as non-conformity with air emission standards in 1990 along with other problems such as federal lawsuits resulting from selling land that was bought for right-of-way by the city and the federal government (Dittmar, 2004). The city for decades experienced unplanned growth with low density and road construction that incentivized the automobile making it impossible to provide quality transit. Under this condition, MARTA decided to build TOD along its rail corridor that had 38 stops with 48 mile of service in an attempt to improve its air quality (Dittmar, 2004). Lindbergh, the system's second busiest station was chosen as the first site for a TOD. Soon after, BellSouth, Atlanta's second largest employer with 20,000 employees decided to relocate to this station, increasing its chances for creating a successful TOD (Dittmar, 2004).

MARTA and BellSouth began to work together to construct plans and designs for the TOD. They didn't include public participation, but once the plans became public, the neighborhood at Lindbergh became stunned, especially with the planned 13,000 parking spaces that would be built in this residential neighborhood, along with the high vehicular traffic it would attract (Dittmar, 2004). Litigation for this and other issues of content such as the lack of affordable housing ensued and this TOD project became marred with controversy, which made investors and developers nervous to build in Lindbergh. With expensive litigations and economic recessions, Atlanta did not have the full budget it initially anticipated (Dittmar, 2004). Hence building sidewalks and other pedestrian-friendly features such as walking bridges that linked the transit system to the TOD and its surrounding neighborhoods was ignored. Furthermore, with the large number of parking spaces, costing about $10,000 per space, the cost of living in these apartments and condominiums was too high compared to other Atlanta regions (Dittmar, 2004). All these factors in addition to the lack of affordable housing made it impossible for most to be able to live in this area.

Based on density, population and the transit characteristics of a transit system, the appropriate transit system should be chosen for an area in order to create a successful TOD. But when good design is absent with no connectivity between the transit stations and the transit-oriented development, the TOD cannot be successful. Furthermore, public participation is crucial in the planning process when creating TOD. When a TOD creates controversy and results in litigation, investors and developers are wary to invest. Additionally, excess parking spaces incentivize driving while increasing the cost for those living in the area.

CHAPTER 5
RESULTS

Five case studies in addition to a case study conducted for South Florida was developed to understand the BRT and heavy rail system: Pittsburgh, Ottawa, Arlington, Pleasant Hill and Atlanta. Pittsburgh and Ottawa use bus rapid transit system, and Arlington, Pleasant Hill and Atlanta use heavy rail systems. Pittsburgh and Ottawa gave insight how BRT systems along with governmental policies can create successful transit-oriented developments. Pleasant Hill, located near San Francisco, and Arlington County gave insight how heavy rail transit systems can create successful TOD. Lastly, Atlanta has MARTA, a heavy rail system, and this case study demonstrated that when policies that address walkability and affordable housing are absent, the TOD along with the transit will most likely not be successful.

From these case studies, the goal was to find the transit characteristics of a transit system that are essential for creating successful TODs. Based on the case study conducted for TOD in South Florida in combination with the five case studies of areas with heavy rail or BRT systems, the transit characteristics that are important for TOD are:

1. Frequency
2. Air pollution
3. Sound pollution
4. Vibration
5. Flexibility of service
6. Transfers
7. Capacity
8. Level of permanence
9. Aesthetics

Description of Transit Characteristics

Frequency

Frequency is a term that explains how often service is provided. For transit to be successful, the frequency must be comparable to the convenience of an automobile, with minimum service being provided once in ten to fifteen minutes (Cervero, 2004). The faster a transit system travels or the greater the number of vehicles available, the more frequent the service will be. In order for a slower transit vehicle to provide service with the same frequency, more vehicles of the slower transit must be utilized.

Air Pollution, Sound Pollution and Vibrations

In TOD, it is crucial that the transit system produces as little air and sound pollution since developments are located a short distance from the transit stations and corridor. Producing as little vibrations as possible is important as property values for a development in a TOD will be higher where air and sound pollution along with vibrations will be kept to a minimum (Diaz, 2007). Furthermore, minimizing air pollution is critical for the health and built environment, where the amount of pollutants and pulmonary diseases is positively correlated. Sound pollution also increases stress levels amongst individuals, hence these transit characteristics should be minimized (Frumkin, 2010).

Flexibility of Service

In areas where density is low, having flexibility of service is essential. If necessary, BRT has the capacity to leave its fixed guideway in order to provide service in other areas to pick up additional passengers. For this transit characteristic, it is important to look for the density and/or population of the area (Dittmar, 2004).

Transfers

As discussed earlier, passengers prefer to be able to ride a transit system with as little need for transfers as possible. The transit system in the FEC that will reduce this will be the better option (Cervero, 1998).

Capacity

As mentioned previously, Ottawa is reaching its maximum capacity for its transit system despite the fact that frequency is high for this system. Hence it will soon be necessary for this BRT system to be retrofitted for a rail system. To understand maximum capacity in context of the South Florida East Coast Corridor Transit Analysis, it is important to look at the projected ridership. If the projected ridership is very high, then BRT may not be the appropriate choice. It is also important to remember that projected ridership may be overestimated (Cervero, 2004).

Level of Permanence

Investors and developers before investing millions of dollars into building developments around transit must be assured that the transit system won't vanish. Hence, this idea of transit having a level of permanence is important in TOD.

Aesthetics

In order for a TOD to be successful, it has to be well designed and aesthetically pleasing. This is also true for the transit system as it must be appealing to those living and working in the area.

Other Aspects of Creating a Successful TOD

It is extremely important to consider how a transit system will impact the land values of properties that are adjacent to the transit in a TOD. This idea ties into the concept of the level of permanence of a transit system. When a transit system goes into an area, it usually increases the values of properties that are adjacent to the system or are at a close proximity. The more a transit system increases property values, the more likely investors and developers will want to finance and develop the TOD.

In addition to analyzing the transit characteristics in order to choose what mode of transit is appropriate for creating TOD, it is also important to look at the density and population of the area it will serve. If an area isn't very dense, then BRT will be the more appropriate choice since the flexibility of the BRT system allows it to also function as a feeder bus before providing service along its fixed route. Hence it is important to look at the density, population, along with the projected ridership to understand if BRT with its smaller capacity or heavy rail, with its larger capacity, is the more appropriate choice for the South Florida region.

CHAPTER 6
ANALYSIS and DISCUSSION

In order to determine whether bus rapid transit or heavy rail is appropriate for creating transit-oriented development, the population and density along Florida's East Coast Corridor must be examined. Based on analysis conducted with Geographic Information System (GIS) using US Census (2000) and Department of Transportation's data, the results of the current population of people living within a close distance of the FEC Corridor in Palm Beach, Broward and Miami-Dade County was found. Table 6-1 shows the results of this data analysis. Figure 6-1 below shows the map of where this data was collected from.

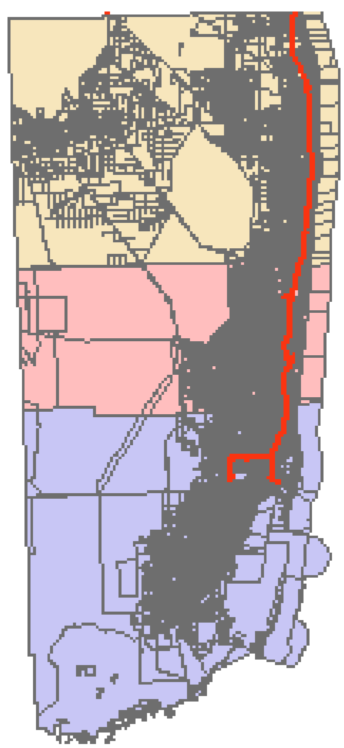


Figure 6-1. Study Area with FEC Corridor

Source: US Census (2000)

Table 6-1. Current Population Adjacent to Florida's East Coast Corridor

County	1/4 Mile Radius	1/2 Mile Radius
Palm Beach	2,583	4,026
Broward	1,868	3,163
Miami-Dade	1,989	3,406

Source: US Census 2000

People are generally willing to walk half of a mile to quarter of a mile to access transit; hence the population within those distances of the FEC corridor was obtained for the three counties. As can be seen, the population along the FEC corridor isn't very high. Based on this solely, it can be seen that bus rapid transit should be more appropriate for this area.

In addition to looking at the population, the density is another measure that can be utilized to determine which mode of transit is more feasible for TOD in South Florida. Looking at Figure 6-2, it can be seen that by the year 2030 there will be some population density concentrated along the FEC corridor. But, it can also be seen that population density overall in the three counties is located more inland rather than along the coastal line or FEC corridor. Furthermore, as shown in Figure 6-3, employment density is also inland rather than along the FEC corridor. Based on these two markers, the population and density along the FEC corridor, it can be deduced that BRT would be the better option. Table 6-2 and 6-3 list which mode of transit, BRT or heavy rail is superior in terms of the transit characteristics that are essential for creating successful TOD as found in the case studies. The transit characteristics of BRT and heavy rail that increase the likelihood of creating TOD and increase their chances of success are shown in Tables 6-2 and 6-3 below.

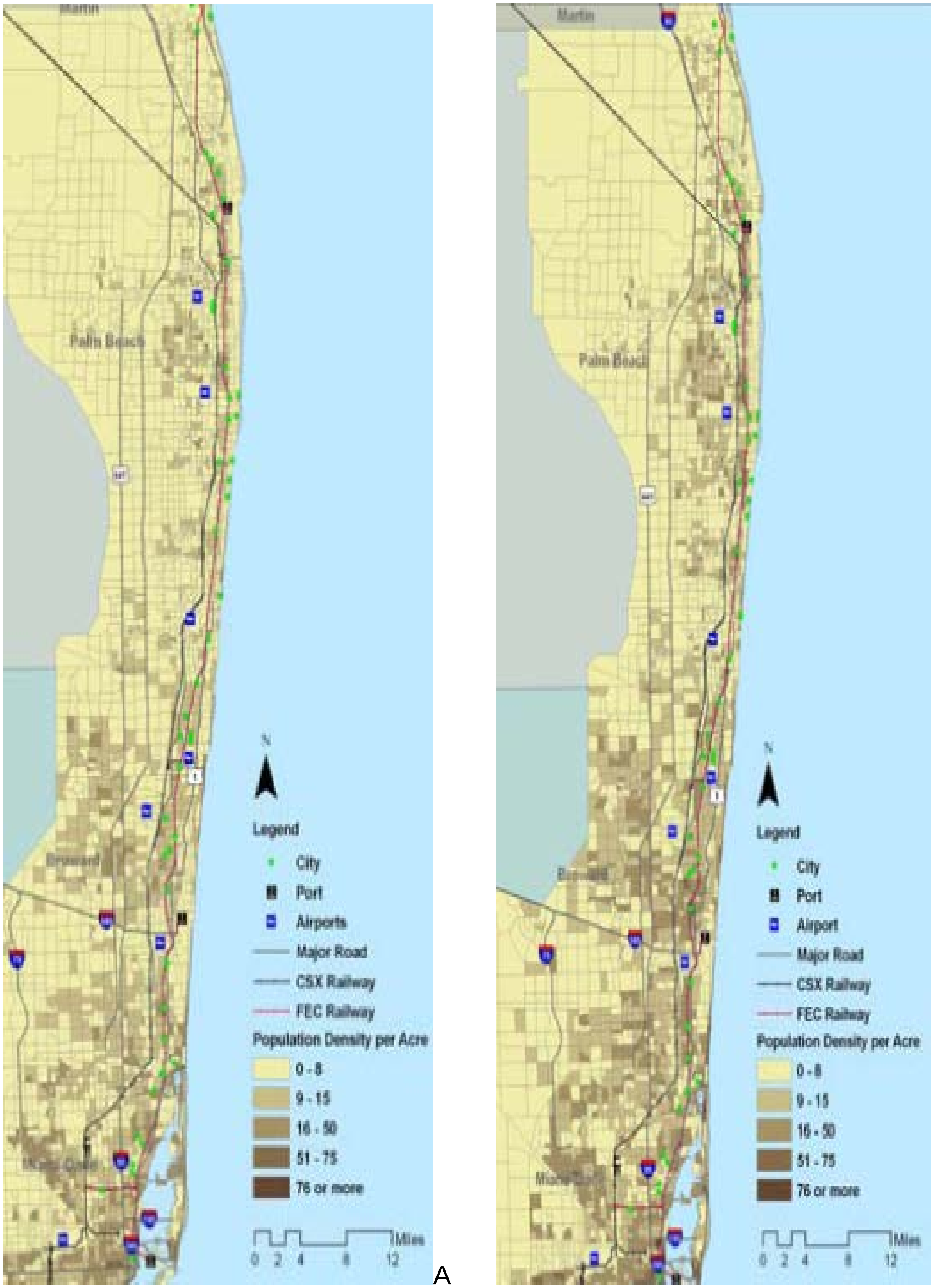
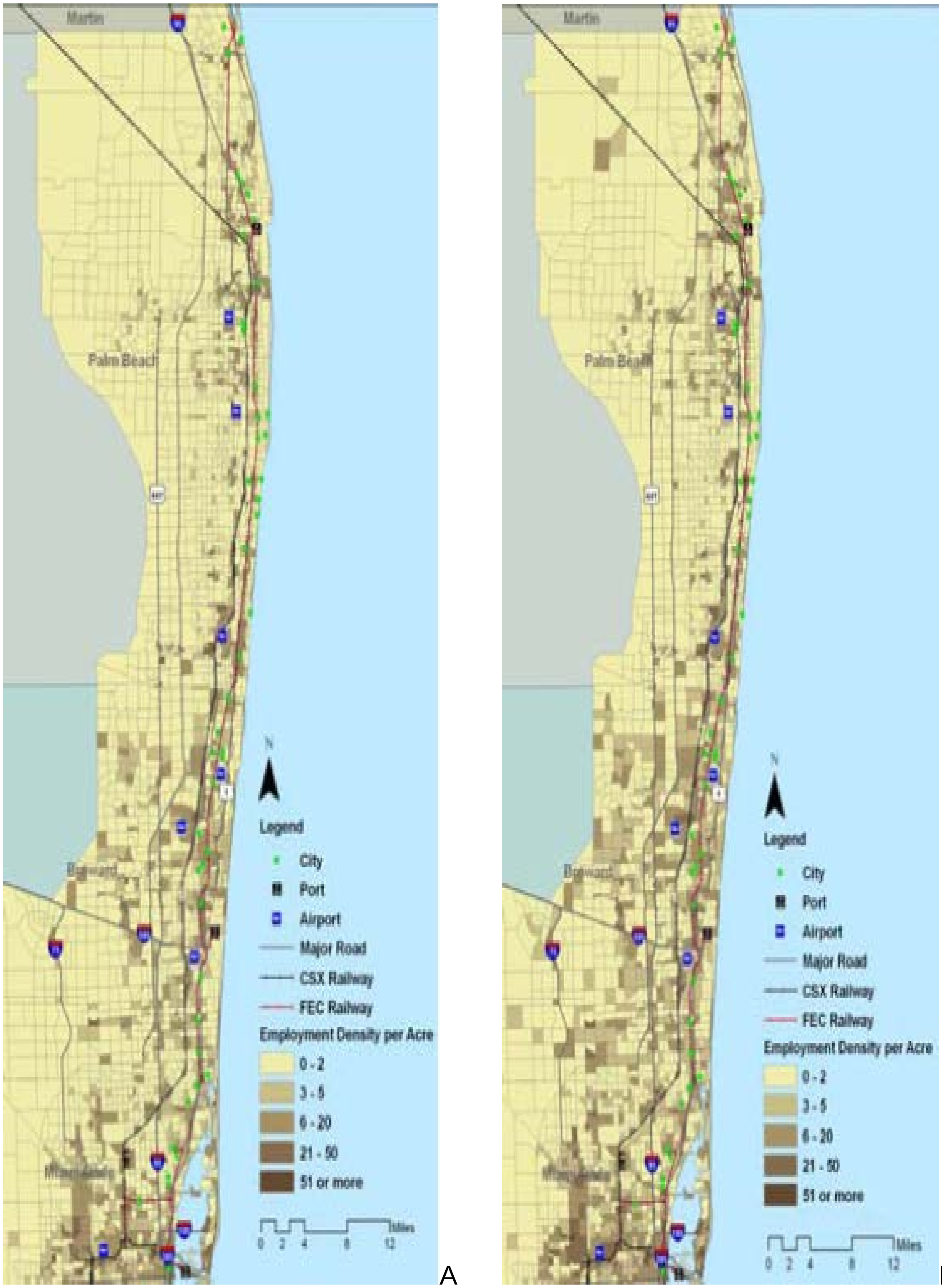


Figure 6-2. Population Density in South Florida. A) year 2000, B) year 2030.

Source: Gannett-Fleming (2006)



A B

Figure 6-2. Employment Density in South Florida. A) year 2000, B) year 2030.

Source: Gannett-Fleming (2006)

Table 6-2 shows the transit characteristics that have a positive impact on TOD. In this table, either BRT or heavy rail is listed as having better frequency, flexibility of service, capacity and aesthetics that matches the needs of Florida's East Coast Corridor.

Table 6-2. Characteristics of Transit that have a Positive Impact on TOD

Positive Transit Characteristics	Bus Rapid Transit	Heavy Rail
Frequency		X
Flexibility of Service	X	
Capacity	X	
Level of Permanence		X
Aesthetics	X	

Source: Own

As shown in Table 6-2, heavy rail has a higher frequency compared to BRT system. Heavy rail as discussed in the literature review travels at 40 miles per hour whereas BRT travels at speeds of 30 to 35 miles per hour (Gannett-Fleming, 2006). Comparing one rail vehicle versus one BRT vehicle, the rail can travel at a faster speed. In order to provide the same level of service with high frequency, more BRT vehicles will be necessary which also increases the capital and operational cost of the transit system. Hence, in terms of frequency, heavy rail is superior.

The flexibility of service is superior in the BRT system where the BRT can be driven off of its fixed guideway to pick up passengers before getting on its fixed-route guideway, the FEC corridor. If South Florida was denser, then rail would be appropriate. But as can be seen in Figures 6-2 and 6-3, the projected employment and population densities for the year 2000 and 2030 shows that the density in the three counties are and will be dispersed. Hence, the BRT system that has the capacity to also be a feeder bus will be more appropriate.

The capacity criterion is derived from the population and density along the FEC corridor. Based on the population living along the FEC corridor and the population and employment density, heavy rail which has a higher capacity (each car can carry 90 to 100 people compared to BRT which carries 78) will not be needed (Gannett-Fleming, 2009). As seen in the case studies, according to the City of Ottawa, 240,000 people utilize this system where 10,000 people are carried one way during peak hours. Pittsburgh, which has a ridership of 34,000 to 37,000 people daily, carries about 3,700 people one direction during peak hours. According to Gannett-Fleming, the projected ridership of transit along the FEC corridor will be about 60,000 passengers daily. The projected ridership for transit along the FEC corridor is higher than Pittsburgh but much lower than Ottawa. According to Harkness, BRT has a capacity of carrying well over 50,000 people in one direction during peak hours (2003). So based on the projected ridership, and the dispersed patterns of population and employment areas, BRT will be the more appropriate choice based on the capacity.

The level of permanence of the system is something important to attract investors and developers to finance and build TOD. In order to accommodate heavy rail, railway tracks must be constructed which increases the capital costs substantially. This shows a high level of commitment from the government that makes the investors and developers feel more confident that building TOD around the rail transit will be successful. Hence, heavy rail is superior compared to BRT in terms of the level of permanence of the system.

Lastly, aesthetics are important for creating TOD. BRT is superior compared to heavy rail since people find rail tracks more visually offensive compared to the normal road surface needed for BRT. While normal buses may be less aesthetically pleasing compared to trains, BRT buses look very similar to light rail vehicles with low floors and other aesthetically pleasing features (Jarzab, 2002).

Table 6-3. Transit Characteristics that have a Negative Impact on TOD

Negative Transit Characteristics	Bus Rapid Transit	Heavy Rail
Air pollution		X
Sound pollution		X
Vibration		X
Transfers	X	

Source: Own

Table 6-3 lists the transit characteristics that have a negative impact on TOD and they are air and sound pollution, vibrations, and transfers. Table 6-4 lists the amount of oxides of nitrogen and hydrocarbons, along with carbon dioxide emitted by the two heavy rail technologies, Diesel Push-Pull and Diesel Multiple Unit (DMU) and bus rapid transit (BRT). Ozone, a pollutant of concern in South Florida is created when oxides of nitrogen (NO_x) react with hydrocarbons (HC).

Table 6-4. Emission of DMU, Push-Pull and BRT

Mode	Oxides of Nitrogen	Hydrocarbons	Carbon Dioxide
Heavy Rail: DMU	4.99 (g/bhp/hr)	0.14 (g/bhp/hr)	1,024,128 lbs/day
Heavy Rail: Push-Pull	5.23 (g/bhp/hr)	0.28 (g/bhp/hr)	979,776 lbs/day
BRT	2.5 (g/bhp/hr)	2.5 (g/bhp/hr)	28,419 lbs/day
* g/bhp/hr: gram/brake horsepower/hour			

Source: Gannett-Fleming, 2010

Based on the results of this table, it can be seen that the heavy rail systems will produce more nitrogen oxide and carbon dioxide compared to BRT, but BRT produces more hydrocarbons. But out of the three pollutants listed, two are higher in heavy rail. Hence, BRT emits less air pollutants and is better for air quality.

Sound and vibration information for BRT and the heavy rail transit was obtained from Gannett-Fleming, the engineering agency conducting research from the South Florida East Coast Corridor Transit Analysis. According to the research, it is clear that sound associated with “Push/Pull and DMU technologies would result in higher numbers of potentially impacted parcels” (Gannett-Fleming, 2009, p. 34). Furthermore, looking at the amount of vibrations caused by heavy rail and BRT system, it was found that “the rail technologies are very similar to each other whereas the bus technologies have much lower vibration sources. In addition, the highest number of potentially impacted parcels are associated with “Regional Rail (Push/Pull) and (DMU)” and the “Rail Rapid Transit” (Gannett-Fleming, 2010, p. 14). Hence, in terms of sound pollution and vibrations, BRT is also superior option compared to the two heavy rail technologies, Diesel Push-Pull Locomotive and Diesel Multiple Units.

As explained earlier, the rail system is 96 miles long and according to the plans, if BRT is implemented, then the 96-mile corridor will be divided into 4 sections, with four separate BRT services being provided to cover the entire corridor. This means that if passengers want to utilize the whole length of the system, then four transfers will be necessary. With the heavy rail system, these transfers will not be necessary. Commuters strongly dislike taking transfers and research has shown that these passengers overestimate the time they actually wait making the transfers (Cervero, 2004). Hence, in this context, heavy rail is superior compared to BRT. This is important because in order for a TOD to be successful, it is important that the transit system be efficient and passengers are comfortable using the system so the need for automobiles is either limited or eliminated.

The question of which mode, BRT or heavy rail has greater land use impacts is a more difficult question to answer. As stated earlier, the impacts of heavy rail and light rail have been compared against normal bus service, but research that focused on rail versus BRT has not been conducted. In Ottawa and Pittsburgh, the BRT systems had an impact on land use, and property values adjacent to the BRT corridors were higher compared to other areas without this transit. Furthermore in Pittsburgh, the demand to live near the BRT system was stronger compared to other areas that were serviced by light rail. On the other hand, in Arlington County and in Pleasant Hill, areas serviced by heavy rail also have had an impact on land uses adjacent to the corridor. Based on these case studies, it can be concluded that BRT and heavy rail both have the potential of changing land use patterns. Through the case studies it also became apparent that the government has to intervene by creating policies that incentivizes density. This is especially the case in South Florida, where market forces alone are not strong enough to create density along the corridor, as evidenced by the sprawling developments.

The case studies in this document show that BRT may not be the perfect transit system for creating TODs in South Florida. Heavy rail has the capability to provide frequent service without the need for more vehicles, appears as a more permanent transit commitment for investors and developers and requires less transfers compared to BRT. Nevertheless, based on the density and population in South Florida, along with the aesthetics, flexibility, and capacity of the BRT system in addition to the fact that it produces less air and sound pollution and has less vibration impacts on properties, that BRT is the more appropriate choice compared to heavy rail. Through implementation of policies that address the deficiencies of the BRT system, issues such as frequency can be alleviated or resolved.

In this research, it was asked which mode of transit, heavy rail or BRT will help create successful TOD along Florida's East Coast Corridor. This question was asked because most transit agencies choose heavy rail or light rail over BRT, despite the fact that BRT is a superior system that is best for areas that don't have the density to support heavy rail. BRT is also a much cheaper option compared to heavy rail. Next, recommendations for policies and actions that transit and other government agencies can implement to alleviate the deficiencies of the BRT will be addressed.

Recommendations

Frequency

High frequency is crucial for transit. Furthermore, if a transit system is inefficient, then the transit-oriented developments that will be built around this transit system will also not be successful. Hence, it is important that local and regional transit and governmental agencies in South Florida address this issue to alleviate this situation. Heavy rail as discussed earlier travels around 40 miles per hour while the BRT travels anywhere between 30 to 35 miles per hour. This difference in speed means that in order for BRT to be competitive to heavy rail, more buses will have to operate to provide frequent service. This is not impossible, as seen in Ottawa, where the headway, or the time needed to travel from one BRT vehicle to the next during peak hours is anywhere from 20 seconds to 1 minute. Ottawa also provides transit service to 240,000 people, whereas the FEC will provide service to 60,000 daily or 25% of the service that Ottawa provides (Judy, 2007). Every bus also carries about 78 people so the headway in Ottawa has to be very short to provide service to the high number of passengers.

Regardless, in order to be competitive to heavy rail, more BRT will have to operate to mitigate for the fact that BRT travels at a slower speed compared to heavy rail.

It is also important to consider that the speed the heavy rail allows for may be unnecessary for the local transit service that will be provided along Florida's East Coast Corridor. Tri-Rail is a commuter rail service that is 71 miles long with 18 stations. Service along the FEC corridor is 96 miles long with 52 stations (Gannett-Fleming, 2010). Tri-Rail uses the two heavy rail technologies investigated for this research, Diesel Push-Pull Locomotive and Diesel Multiple Units and these railcars travel at about 40 miles per hour. Even if the results concluded from this research indicated that heavy rail would be the better option for the FEC corridor, it may not be practical for the railcars to travel at 40 miles per hour with frequent stops. Hence, the fact that these heavy railcars can travel at faster speeds may not be pertinent in a local transit service. Further research that will look at what frequency of service will be necessary for providing sufficient local transit service along the FEC corridor will help answer this question. Results from that analysis will find the optimal speed that BRT should travel at to provide the frequency of service needed along the FEC corridor based on the projected ridership.

Level of Permanence

Developers and investors prefer rail to BRT since the infrastructure needed for rail, the rail tracks, appear to be a more permanent commitment compared to the normal roads that BRT utilizes. Furthermore, the capital cost associated with building rail is much higher than BRT and this expensive investment made by the government makes developers and investors feel more confident when financing and building TOD (Cervero, 1998). But the government can take different actions that can make the investors and developers feel more comfortable. For example, the capital costs are going to be much lower when installing the bus rapid system. But the transit stations should be of the same quality as it would be for heavy rail and the government should contribute large funds to provide for this. By building stations that are of high quality with retail activities such as restaurant and shops, a level of permanence is established (Judy, 2007).

Investments should also be made by the government by creating landscaped, well-light walkable areas with easy pedestrian access to the transit stations coupled with bicycle lanes. Building such an established infrastructure will give investors and developers confidence that this transit system will remain in the area. Currently, local agencies in South Florida such as Florida's Department of Environmental Protection are promoting building a shared-use pathway along the FEC corridor in conjunction with the transit system. Since South Florida has warm temperature throughout the year, this will help promote bicycle tourism into the area along with a healthier lifestyle for the residents of Palm Beach, Broward and Miami-Dade County. By investing in these additional features which makes this transit corridor more attractive, investors and developers will realize that just because the bus rapid transit system doesn't have the expensive rail tracks doesn't mean that this transit system isn't permanent.

Transfers

As discussed earlier, if BRT is chosen by the South Florida East Coast Corridor Transit Analysis as the mode of transit that will be implemented, then the 96-mile corridor will be divided into four sections. As Cervero said, passengers dislike transfers because of the waiting time that is associated with making transfers. But there are things that can be done to help improve this system. In order to improve efficiency, when passengers get off of a BRT vehicle, there should be buses waiting to pick them up immediately with very little delay for the next segment. Easy access should be given to all passengers, especially for disabled passengers so that the necessary transfers are seamless. Furthermore, frequency of service should be very high especially at the stations where transfers will be necessary so that waiting time is minimized.

One important aspect of the transit system that is also important to consider is that FEC will provide local service which will be integrated with the Tri-Rail system, the commuter rail system. Service between these two transit systems will be seamless and passengers will be able to transfer between the two systems depending on their travel needs. If passengers choose to travel great distances, they can use the Tri-Rail system and get off at one of the four transfer stations and use the FEC BRT system for the remainder of their trip for local service.

It is also important to consider that BRT will be used north of West Palm Beach starting from the town of Tequesta regardless of what mode is finally chosen. If the heavy rail system is implemented, then passengers will need to transfer between that feeder bus service onto heavy rail. Furthermore, if BRT system is implemented, it can provide flexible service where it can get off the FEC corridor if necessary to pick up passengers in lower density areas and then get on the corridor. Since BRT is being used as a feeder bus system from the town of Tequesta to West Palm Beach, continuing the BRT system will lessen the need for a transfer compared to heavy rail. Regardless, more transfers are needed for the BRT system compared to heavy rail, but the negative impacts can be minimized by making this system more seamless with high frequency of service especially at those four transfer stations. By following recommendations such as these, the detrimental BRT characteristics can be reduced which will more likely make the TOD along with the BRT system successful.

Gannett-Fleming is an international consulting firm that specializes in engineering, design, planning and construction management services. This firm is conducting research for the South Florida East Coast Corridor Transit Analysis and their sound pollution, vibration and density analysis along with other information has been essential for this thesis. They addressed many different issues in their research, but the major issue that was not addressed is that there isn't high population and employment density in Palm Beach, Broward, and Miami-Dade County along the FEC corridor. This issue is vaguely discussed in the "Purpose and Need" Tech Memo, but thorough discussion about the lack of density with much urban sprawl and what its implications are in South Florida is not included in their research. Robert Cervero stressed the importance of density for the success of TOD and transit systems and this key factor was overlooked by Gannett-Fleming.

There were limitations to this research. As discussed earlier, information and research regarding the impact of BRT on land use is not sufficient. Case studies for Ottawa and Pittsburgh attempted to address this issue, but more research needs to be conducted. Furthermore, while population and employment density maps based on the population forecast up to the year 2030 helped determine which mode of transit will be more appropriate for the coastal areas of the three counties, research that looks at the impacts of climate change on sea level rise was not included. According to Climate Progress, a project looking at Climate Change, housing and commercial market near coastal cities will peak around 2020. Based on the projections of how weather patterns and shorelines are rapidly changing, investments in coastal areas will decrease, especially since insurance companies will become more hesitant to provide insurance to coastal properties (2009). Though sea level rise was not included when comparing BRT and heavy rail, it is important to note that if coastal areas start losing population, then BRT will be superior since it will not be confined to the rail corridors along the coastal areas. Furthermore, if emergency situations arise where residents may need to evacuate coastal areas, BRT will be capable of moving people out of the region more easily. So in addition to having the capability of providing flexible transit service in low-density areas, BRT can also provide service if events relating to sea level rise or emergency evacuation occurs.

In this thesis, it was found that BRT system should be implemented, but there are some implications associated with BRT that are important to consider. Though the BRT system may be clearly superior to rail in this area, this will probably not be the locally preferred alternative. As discussed earlier, there are social stigmas attached to the bus where buses are thought of as being dirty and only the economically disadvantaged choose to ride this system. But BRT is not just some kind of city bus system that is stuck in traffic. The buses that are used by BRT systems found in cities such as in Pittsburgh look and function similar to the rail vehicles, especially light-rail vehicles. Every day, 240,000 people ride this system in Ottawa and land values adjacent to this system are much higher. But until more of these systems are implemented in the US, cities will most likely consider BRT the second choice option. The only logic behind this choice may be their cheaper price tag regardless of the attractive BRT features such as its flexibility in low density areas.   Furthermore, unfortunately in the short term, since people are attracted to rail systems, rail systems may have greater transit ridership compared to the BRT.   Pittsburgh is some sense is the only example of TOD around BRT in the US (Jarzab, 2002).   Until more examples of successful TOD around the BRT systems can be shown to transit agencies and regional and local governments, the BRT system will most likely not be the locally preferred alternative.

In order to contribute to the success of TOD around the BRT system, cities will have to be proactive as they are in Pittsburgh and Ottawa. In Ottawa, the political system allows for the government to have stronger policies for land use development, but local governmental agencies in the US can help attract developers to land adjacent to the FEC corridor. By providing incentives such as higher densities, and assistance through land banking and land assembly, developers will more likely be enticed to develop in the area. Furthermore, it is important that the local and regional agencies involve the public as soon as possible to get their inputs in order to alleviate their concerns and solve problems beforehand. This will help assure that when developers begin working, they will not face costly and time consuming ligations as seen in Atlanta. Efforts have been made and are currently occurring to involve the public in the South Florida East Coast Corridor Transit Analysis through charrettes and public workshops to get the public's input about this proposed transit system.   Through these types of actions, this region can help build a successful transit system where successful TOD will occur.

In addition to all these recommendations, it is important to remember that TOD must be places that are built for people where they would want to live, work and play. It is important that the area is very walkable with well-designed pedestrian and bicycle friendly spaces that allow for easy access to the transit stations. A sea of parking spaces will not make a TOD successful. As seen in Ottawa, only some stations along the transit system should cater to the needs of those who will park and ride. But those park and ride stations should not be located in transit-oriented areas.

In Atlanta, what was seen was that the connectivity for those living outside the TOD to the transit stations was non-existent. There were no pedestrian bridges or sidewalks that connected the area. First, it is important to remember that a TOD cannot be successful if the transit system it utilizes is not successful. So if more people from outside the TOD walk to the transit station, they are more likely to shop and eat at areas in the TOD, contributing to its economic success as well as making the area more vibrant with activity. Moreover in time, those people who will walk to the TOD will realize how attractive it can be to live in the TOD, further making the area more successful. Hence, it is essential that connectivity in the form of pedestrian and bicycle features that are safe and well lit are provided for those who will access the TOD and the transit system from outside the area.

Lastly, it is important to remember one of the crucial reasons why it is necessary to build TODs along the FEC corridor. People in households without cars need to have access to transit so they can get to their jobs, drop their children to school, and have access to grocery stores close to their homes; activities that will allow them to become a productive member of society. Many families do not have the luxury of being able to afford cars, and it is important that when developers build residential units they also include affordable housing units in these developments. In California, along the BART system, some cities have done a great job creating and enforcing policies that have created affordable housing where people have easy access to grocery shops and recreation activities. Though initially it was expensive for the city to do this, with time the cities realized that the crime rates in the area dropped substantially along with the percentage of people unemployed and/or people utilizing the Supplemental Nutrition Assistance Program (Boarnet and Compin, 1999).

In the South Florida East Coast Corridor Transit Analysis, different modes of transit are being considered to provide a local transit service with frequent stops along Florida's East Coast Corridor. After years of continued growth with the wetlands in the Everglades National Park being drained for developments, the government has placed a growth boundary to prevent to this from further occurring. Now the South Florida region wants to develop with density along the coast and initiatives such as Eastward Ho will allow for this. Transit-oriented developments are an effective tool that cities across the United States are utilizing to create mixed-use areas that are dense and these areas can be serviced efficiently by transit. By implementing a BRT transit system, South Florida has the potential of creating successful TODs to increase density while providing a local public transit system.

Further Research Recommendations

Research regarding light-rail versus bus rapid transit is very common. But research that looks at heavy rail versus bus rapid transit is not common even though cities are comparing these two systems for their alternatives analysis. Further research should be conducted that will allow cities to gain an understanding of which transit system to choose because it is not about which system is superior overall, but which mode is appropriate for a region. Also most transit-oriented developments are built around rail systems in the United States, not BRT. One of the limitations in this research was the lack of knowledge about what the impact of BRT is on land values and how it can change land use patterns. Most scholars said that BRT cannot change land use patterns as much as rail, but those scholars were comparing city bus routes to rail, not BRT with its designated guideway to rail.

One of the biggest issues with BRT is that most city planners and officials are not educated about this transit system and believe that BRT is just another technical name for a city bus system. Case studies that focus on how city planners and officials in Latin America, Canada, Australia and Europe implemented this system on a large scale in densely populated areas where TOD resulted will be hugely beneficial for cities that are considering implementing this system in the United States.

CHAPTER 7
CONCLUSION

Palm Beach, Broward and Miami-Dade County in South Florida have the potential for creating successful TODs along Florida's East Coast Corridor. When creating TOD, it is very important to consider which mode of transit is utilized because if people choose to not use a transit system because it isn't convenient for that particular area, then people will not wish to live in a TOD that is adjacent to that transit system. When TODs are created in the United States, most times as seen in Atlanta, it is adjacent to a rail system, even if rail is not the appropriate transit for that area. On the other hand, BRT system which is a very efficient system with high potential for creating successful TOD (as seen in the Pittsburgh and Ottawa case studies) is not the preferred mode of transit for TOD compared to rail.

In this thesis, it was investigated which mode of transit, heavy rail or BRT has the potential for creating TOD along the FEC corridor in Miami-Dade, Broward and Palm Beach County. It was found that in South Florida, due to office spaces, retail and residential areas not being strongly agglomerated along the FEC corridor, the density and population that should exist to support a heavy rail system like in Chicago or New York City, does not exist. Rather BRT can provide better service in these counties since BRT has the capability unlike rail to provide service on local roads in low density areas before utilizing its designated guideway. Furthermore, it was investigated through case studies what transit characteristics are important for creating successful TOD. As stated earlier, in order for a TOD to be successful, the transit system that the TOD is adjacent to must be efficient and passenger-friendly. So the transit characteristics that were found to be very important are: the frequency, the flexibility of service, the passenger capacity that matches the projected ridership, the level of permanence, and which mode is more aesthetically pleasing. Transit characteristics that were found to have a detrimental impact on TOD are vibration, sound and air pollution, as well as the number of transfers necessary for passengers to take when using that system. The two heavy rail alternatives, Diesel Push-Pull Locomotive and Diesel Multiple Units, are being considered for the FEC corridor and the heavy rail technologies were compared to bus rapid transit system based on each characteristic. Based on the comparison of the transit characteristics in conjunction with the current population and the density of population and employment in 2000 and 2030 adjacent to the FEC corridor, it was found that BRT is the appropriate choice for TOD along the FEC corridor in South Florida.

Implementing a BRT system will be the most appropriate choice in South Florida that may help create vibrant TODs along Florida's East Coast Corridor. It is important to remember that BRT is an attractive system with many modern features. It isn't an old, dirty, loud bus but rather it is sleek with clean technology, low floored for easy access for passengers, efficient with its own designated guideway, and aesthetically pleasing with well-developed transit stations. Marketing the BRT system as this instead of just another bus route will be crucial for its success and this will make investors, developers and residents of the area excited about this project. In turn, this may create TODs in South Florida where people will be excited to live, work and play.

LIST OF REFERENCES

Bae, C. (1993). Air quality and travel behavior: Untying the knot. *Journal of American Planning Association, 59*, 65-75

Belzer, D., & Autler, G. (2002). Transit Oriented Development: Moving from Rhetoric to Reality. Washington, DC: Brookings Institution Center on Urban and Metropolitan Policy.

Blakely, H.J. & Bradshaw, T.K. (2002). *Planning Local Economic Development: Theory and Practice.* Thousand Oaks, California: Sage Publications

Boarnet, M. G. & Compin, N. S. (1999). Transit-Oriented Development in San Diego County-The Incremental Implementation of a Planning Idea. *Journal of the American Planning Association*, *65* (1), 80-95. doi:10.1080/01944369908976035

Bürer M., & Goldstein. (2004). Location Efficiency as the Missing Piece of The Energy Puzzle: How Smart Growth Can Unlock Trillion Dollar Consumer Cost Savings. *Natural Resources Defense Council.* Retrieved February 19, 2011, from http://docs.nrdc.org/air/files/air_06031001a.pdf

Burden, D. (1999). Street Design Guidelines for a Healthy Neighborhood. *TRB Circular E-C019: Urban Street Symposium*

Bureau of Economic Research. (2007). 25 Most Populated Cities in Florida. Retrieved November 20, 2010, from http://www.bebr.ufl.edu/files/snowbirds_0.pdf

California Department of Transportation. (2002). Statewide Transit-Oriented Development Study: Factors for Success in California. Sacramento: Business, Transportation, and Housing Agency.

Calthorpe, P. (1993). *The Next American Metropolis: Ecology, Community and the American Dream.* New York: Princeton Architectural Press.

Cervero, R. (1998). *The Transit Metropolis: A Global Inquiry*. Washington DC: Island Press

Cervero, R., & Michael D. (2002). Transit's Value-Added: Effects of Light and Commuter Rail Services on Commercial Land Values. Retrieved January 6, 2011, from http://www.apta.com/research/info/briefings/documents/cervero_duncan.pdf

Climate Progress. (2010). Coastal Properties and the Environment. Retrieved March 2, 2011, from http://climateprogress.org/2010/11/14/sea-level-rise-planning-coastal-infrastructure/

Currie, G. (2006). Bus Transit Oriented Development: Strengths and Challenges Relative to Rail. *Journal of Public Transportation 9*(4), 44-76

Daisa, J. (2004). *Traffic, Parking, and Transit-Oriented Development. The New Transit Town in Transit-Oriented Development.* Washington DC: Island Press.

Diaz, R. (2007). Impacts Of Rail Transit On Property Values. *Business and Community Development.* Retrieved January 5, 2011, from http://www.rtd-fastracks.com/media/uploads/nm/impacts_of_rail_transif_on_property_values.pdf

Dittmar, H., Ohland, G., & Poticha, S. (2009). *The New Transit Town: Best Practices in Transit-Oriented Development.* Washington DC: Island Press

Environmental Protection Agency. (2008). Energy Efficiency Actions. Retrieved September 28, 2010, from http://www.epa.gov/statelocalclimate/state/tracking/individual/fl.html

Federal Transit Administration. (2001). New Starts Project Planning & Development. Retrieved January 15, 2011, from http://www.fta.dot.gov/planning/planning_environment_5221.html

Frumkin, H. (2010). *Environmental Health: From Global to Local*. San Francisco, CA: Jossey-Bass

Fuhs, G. (2009). Washington DC-Purple Line Analysis. Retrieved February 4,2011, from http://www.embarq.org/en/project/washington-dc-purple-line-analysis

Galvez, Janet. (1997). The Florida Elusive Snowbird. Bureau of Economic Research. Retrieved November 20, 2010, from http://www.bebr.ufl.edu/

Garrett-Fleming. (2006). South Florida East Coast Corridor Transit Analysis (SFECCTA) Purpose and Need. Retrieved August 16, 2010, from http://www.sfeccstudy.com/documents.html

Garrett-Fleming. (2009). Air Quality, Noise and Vibrations Tech Memo. Retrieved September 15, 2010, from http://www.sfeccstudy.com/documents.html

Giuliano, G., & Hanson, S. (2004). *The Geography of Urban Transportation (*3rd ed)*.* New York: The Guilford Press.

Ingram, G., & Liu, Z. (1997). Determinants of Motorization and Road Provision. World Bank Policy Research Working Paper No. 2042. Retrieved March 5, 2010, from http://ssrn.com/abstract=569257

Jarzab, J. (2002). Characteristics of Bus Rapid Transit Projects: An Overview. *Public Journal of Transportation*, *5*(2), 31-46.

Judy, M. (2007). The Potential for Bus Rapid Transit to Promote Transit-Oriented Development: An Analysis of BRTOD in Ottawa, Brisbane, and Pittsburgh. (Master's Thesis). Massachusetts Institute of Technology, Cambridge, MA

Koonce, P. (2009). Bus Rapid Transit and Development: Policies and Practices that Affect Development Around Transit. *Federal Transit Administration*: FL-26-7109.2009.5

Lund, H., Cervero, R., & Wilson, R. (2004). Travel Characteristics of Transit-Oriented Development in California. *Statewide Planning Studies.* FTA Section 5313

Polzin S. and Baltes, M. (2002). Bus Rapid Transit: A Viable Alternative? *Public Journal of Transportation*, *5*(2), 47-70

Lang, R. (2003). Beyond the Edge City: Office Sprawl of South Florida. *Center for Urban and Metropolitan Policy*, The Brookings Institution.

Nakamura, H., Giuliano, G., & Sperling D. (2004). *Urban Transport and the Environment: An International Perspective*. Oxford: Elsevier LTD.

Nelson, D., and J. Niles. (1999). Market Dynamics and Network Travel Patterns: Obstacles to Transit-Oriented Development? *Transportation Research Record.* National Research Council, 13-21.

Niles, J., and D. Nelson. (1999). Measuring the Success of Transit-Oriented Development: Retail Market Dynamics and Other Key Determinants. *Proceedings of the American Planning Association National Planning Conference*. Seattle, WA.

Solsby, Jeff. (2009). Stimulus-Funded Infrastructure Investments Working—Time Now for Quick Action on Strong Federal Highway & Transit Investment Bill, ARTBA Leader Tells Congress. Retrieved November 2, 2010, from http://www.artba.org/

South Florida Regional Transportation Plan 2035. (2010). Retrieved October 25, 2010, from http://www.seftc.org/tp/docs/2035

South Florida Regional Planning Council. (1998). Eastward Ho: An Executive Summary. Retrieved October 25, 2010, from http://www.sfrpc.com/eho.htm

Statistics Canada-Census. (2001). Ottawa Population and Density. Retrieved March 1, 2011, from http://www.census2011.gc.ca/

Tann, H. (2009). Land Use Impacts of Bus Rapid Transit: Effects of BRT Station Proximity on Property Values along the Pittsburgh Martin Luther King, Jr. East Busway. Federal Transit Administration: FL-26-7109.2009.6

United States Census Bureau. (2000). Population and Population Density for 2000. Retrieved February 25, 2011, from http://www.census.gov/

Vuchic, V. (2002). Bus Semirapid Transit Mode: Development and Evaluation. *Journal of Public Transportation*, 5(2), 71-96

Wohlwill, D. (1996). Development Along a Busway: A Case Study of Development Along the Martin Luther King, Jr. East Busway in Pittsburgh, Pennsylvania. 1996 APTA Rapid Transit Conference, Atlanta, GA,

Wright L., & Hook W. (2007). *Bus Rapid Transit Planning Guide*. New York: Institue for Transportation and Development Policy.

BIOGRAPHICAL SKETCH

Tamashbeen Rahman was born in Dhaka, Bangladesh and immigrated to the United States at a young age. She received her bachelor's degree in biology with a minor in biomedical physics at the University of South Florida. Upon graduation, she worked at a medical research lab for two years at the University of Florida testing treatments for osteoporosis in menopausal women. During this time, she decided to alter her career path and pursue a master's degree with some focus on environmental protection.

Tamashbeen, in summer 2010, completed an internship at the Department of Environmental Protection where she studied the impacts of transportation and planning on air quality in South Florida. During this time, she was introduced to Florida's East Coast corridor project and the different transit alternatives. Upon graduation, Tamashbeen hopes to return to South Florida with her husband, live in a TOD, and pursue a career in environmental protection, transportation and planning.