Impacts of Transit in a Complete-Streets Context

By

Virginia Sisiopiku, Md. Shah Imran, and Abdul Muqueet Abro
Department of Civil, Construction, and Environmental Engineering
The University of Alabama at Birmingham

Prepared by

UTCA

University Transportation Center for Alabama
The University of Alabama, The University of Alabama at Birmingham,
and The University of Alabama in Huntsville

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16. Abstract

The recent interest in smart growth, livable communities, and sustainability creates new opportunities for the adoption, expansion, and enhancement of transit services in communities across the U.S. Given that promoting livability and alternative modes is a key priority in the US DOT's agenda, research on economic impacts from integration of transit is both timely and essential. This is important as many of the possible gains from such integration are not fully understood and properly measured to date, such as the related health and quality of life benefits.

This project analyzes the economic impacts from the implementation of a transit improvement project in a community. The project plan includes expansion and re-design of transit routes to better serve local needs, necessary provisions to accommodate transit user needs (such as a central station terminal, stops, shelters, etc.), as well as supporting infrastructure design changes to maximize access to public transportation and to encourage transit ridership in mixed-use residential/commercial areas. The project presents a detailed transit improvement plan and then identifies associated costs and benefits from the investment for the users and community as a whole.

This analysis is expected to help transportation planning, transit, and health professionals better coordinate their efforts to create a more "livable" environment in the community studied and to serve as a model for other communities that are interested in considering viable alternatives which can offer citizens healthier and more sustainable transportation choices.

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List of Abbreviations

B/C	Benefit-cost
BCA	Benefit-cost analysis
BJCTA	Birmingham-Jefferson County Transit Authority
BRT	Bus Rapid Transit
BTOD	Bus Transit-oriented development
CNG	Compressed Natural Gas
CO	Carbon monoxide
DGE	Diesel gallon equivalent
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	Geographic Information System
I-O	Input-output
MDC	Medical conditions
NO_x	Nitrogen oxides
NPV	Net Present Value
O-D	Origin-destination
PBQD	Parsons Brinckerhoff Quade & Douglas, Inc.
PM	Particular Matter
PM_{10}	Particulate matter of 10 micrometers or less aerodynamic diameter
$PM_{2.5}$	Particulate matter of 2.5 micrometers or less aerodynamic diameter
RTOD	Rail Transit-oriented development
SO_x	Sulfur oxides
TAZ	Traffic Analysis Zone
TCRP	Transit Cooperative Research Program
TOD	Transit-oriented development
RPCGB	Regional Planning Commission of Greater Birmingham
VMT	Vehicle Mile Traveled
VOC	Volatile organic hydrocarbon

Executive Summary

The recent interest in smart growth, livable communities, and sustainability creates new opportunities for the adoption, expansion, and enhancement of transit services in communities across the U.S. Given that promoting livability and alternative modes is a key priority in the US DOT’s agenda, research on economic impacts from integration of transit is both timely and essential. This is important as many of the possible gains from such integration are not fully understood and properly measured to date, such as the related health and quality-of-life benefits.

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Section 1
Introduction

1.1 Introduction

Personal automobiles are the most popular means of transportation in industrialized nations. In the U.S., interstate system expansion, coupled with rapid urbanization, suburbanization, and the low prices of automobiles and fuel, led to a rapid increase in automobile ownership and use. Once a symbol of status and independence, the automobile gradually burdened American society with congestion, lost productivity, air pollution, dependence on foreign oil, and thousands of traffic fatalities and injuries year after year.

Public transportation was another victim of automobile dependency in the U.S., and most urban transit systems experienced a steady decline in transit ridership as a result of increased automobile use and city expansion (Jerby and Ceder 2006). According to a study by Larwin (2005), today less than 10% of U.S. citizens use public transit regularly. This forces transit system providers to depend on government subsidies.

This struggle for survival among transit systems cannot be overlooked. Availability of public transportation is crucial to ensure mobility and accessibility to all people, including those who cannot drive (e.g. children, the elderly, and the physically impaired) and those who do not have access to an automobile and depend on public transit to access work or school, healthcare, and daily needs (Jones, *et al*. 2006). Plus, as international experience confirms, high-quality public-transportation service is an effective and sustainable option for moving the public, and many experts argue it is a vital, and perhaps the only, solution out of the gridlock that results from automobile dependency. Not only is public transportation essential for the well-being of residents and the environment but also improvements in the public transit network coverage have a great effect on the local economy, community prosperity, and growth (CSEDRG 1999).

1.1.1 The Role of Transit in Meeting Mobility Needs

The literature recognizes the role of public transit in meeting mobility needs, and providing transportation choices while simultaneously helping to address environmental concerns and promoting community sustainability. Figure 1-1 illustrates the role of transit and ridesharing in improving mobility and reducing congestion and parking problems. Figures 1-2 and 1-3 show the net vehicle and pedestrian congestion reduction benefits (under urban-peak and urban off-peak conditions) and pollution-reduction benefits (given a shift to diesel buses carrying 20 passengers. There are larger benefits for compressed natural gas [CNG], hybrid, or electric-power transit vehicles) due to shifts from automobile to buses respectively.

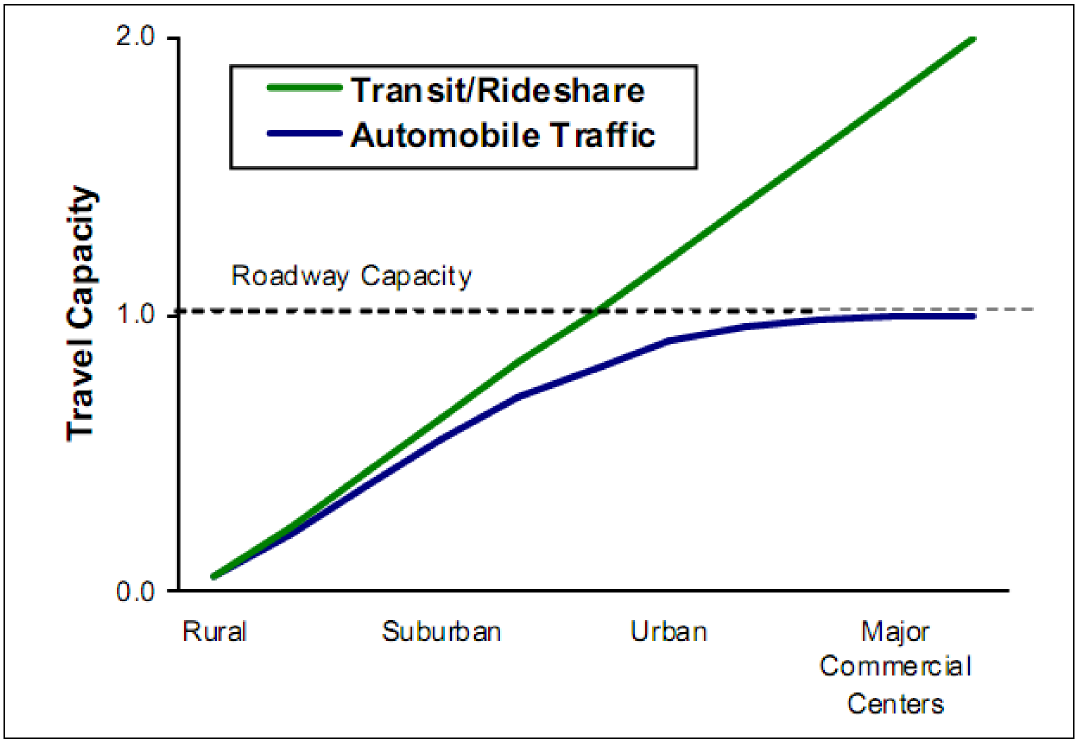

Figure 1-1. Impact of transit on urbanization (Litman 2012)

Transportation system travelers can be classified as transit riders and non-transit users. Transit riders can be further classified as choice users and captive users. Choice users seek a realistic transit option that meets their transportation needs. When the transit option is considered superior to other choices in terms of time, cost, convenience, and comfort, people choose transit systems. Captive transit users do not have a viable option other than transit and are bound to public transportation because of age, disability, income, or family circumstances (Beimborn, *et al*. 2003). According to Rosenbloom and Fielding (1998), women, racial minorities, immigrants, workers age 17 to 29, workers with low incomes, and workers with no household cars need transit to commute to work. About 30% of the population 5 years old or older in the U.S. is identified as transit-dependent, accounting for about 70% of all transit trips (Polzin, *et al*. 2000).

Planners report that low-income families are less likely to own automobiles and mostly depend on public transportation for travel (Sanchez, *et al*. 2004). Therefore, adequate access to public transit (e.g. a transit station within viable walking distance from their residences) is required to fulfill their daily needs. Physical access to public transit and the degree of access to job opportunities affect employment opportunities (Yi 2006). Most transit systems provide low frequency service or do not operate at night or on weekends, when many of the less skilled are at work (Cervero, *et al*. 2002). The McCone Commission (Sanchez 1999) found a link between the high rate of unemployment among African-Americans in central cities and the inadequate public transportation system in low-income neighborhoods. The role of transit for serving the mobility needs of poor and disadvantaged populations and supporting social and equal opportunity objectives is undeniable.

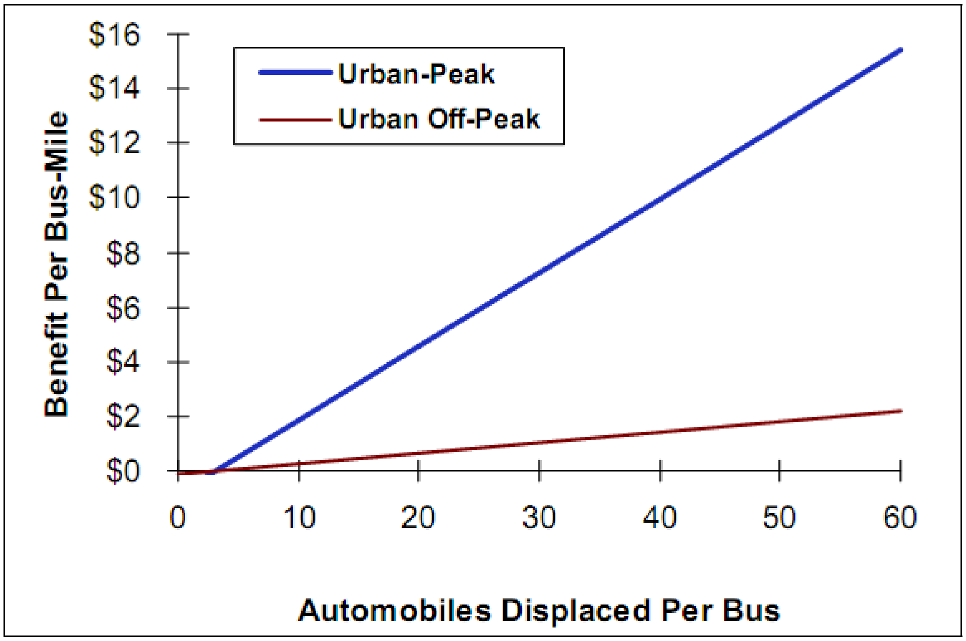

Figure 1-2. Congestion reduction benefits from automobile to bus shift (Litman 2012)

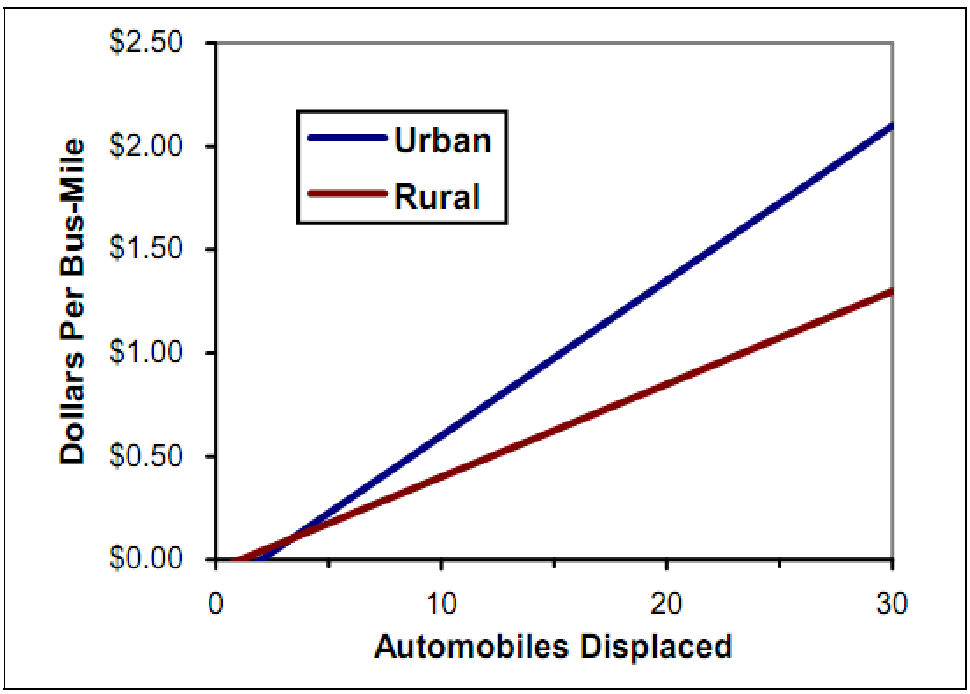

Figure 1-3. Pollution reduction benefits from automobile to bus shift (Litman 2012)

The non-transit users can also be divided into two groups: captive automobile and choice automobile users. Automobile captive users are required to use their automobile for a variety of reasons, such as lack of transit service connecting origin or destinations, scheduling limitations, need to carry large objects, etc. (Beimborn, *et al*. 2003). On the other hand, choice automobile users may be candidates for transit use if the transit system provides choices that are perceived as more beneficial than the automobile. Given an availability of transit options and traveler choices, a traveler may select transit when considering connectivity, comfort and convenience, accessibility to a stop, service reliability, wait time and travel time, cost, security, and amenities in the vehicle or at the stop, etc. All these factors influence the decision making process of transportation users (Beimborn, *et al*. 2003).

1.1.2 The Role of Transit as Part of Complete Streets Community Transformation

Recently transit has been viewed as a change agent to transform a community. Many communities have joined the growing national movement to make their streets meet the needs of people of all ages, abilities, vehicle ownerships, and social statuses. The idea has been termed *complete streets*. Transit is often an integral part of the complete streets; this is referred to as *transit-oriented development* (TOD). The movement redefines the role of street, the goals of transportation agencies, and transportation expenditures. The complete-streets approach focuses on the safe transportation of all users rather than dealing with the traditional separation of highways, transit, and biking/walking facilities (Seskin and McCann 2008).

The complete-streets paradigm uses principles of land-use planning, transportation-facility design, and transportation-system management to promote sustainable community growth and to provide all users transportation options. This is in theories and guidelines proposed in smart growth, new urbanism, and TOD references to promote sustainable community growth and transportation options for all users (Dill 2008). TOD is designed to maximize access to public transport in a mixed-use residential or commercial area, often incorporating features that encourage transit ridership. A transit station or stop (train station, metro station, tram stop, or bus stop) is usually the center of a TOD neighborhood. The station or stop is typically surrounded by relatively high-density development with lower-density development progressively spreading out from the center. The standards for good TODs are high-density locations, with a good land-use mix, availability of pedestrian-friendly amenities, and close proximity to transit service, though no neighborhood completely satisfies all the conditions (Cervero, *et al*. 2004; Dittmar and Ohland 2004; Dow 2001; Dunphy and Porter 2006).

According to Cervero, *et al*. (1996), urban density influences transit ridership. Luscher (1995) confirms that urban density is a key factor affecting TOD's ability to shift trips from automobile to transit. In fact, TOD works best with developments that contain a mix of uses such as housing, jobs, shops, restaurants, and entertainment. It provides options for people to walk, bike, or ride on transit, thereby increasing "location efficiency" and boosting transit ridership. It also supports housing, shopping, and transportation-choice alternatives and generates revenue for the public and private sectors. The literature confirms that TOD provides value for both new and existing residents; hence, it creates a sense of place (Strategic Economics 2009).

TODs are typically designed to maximize walking trips and access to transit within a half mile of a transit stop or station. According to TOD, bicycle lanes, shelters, and other non-motorized user amenities should be provided at or near stations or stop areas to promote accessibility to stations and transit stops and user convenience. Based on the literature, most people are willing to walk for five to ten minutes, or a quarter mile to half a mile. When planners choose a location for TOD, the intensity and density of developments should be the highest within the first quarter mile (approximately 125 acres) around the transit station (transit core). The TOD related improvements may gradually decrease out to the half-mile radius (transit neighborhood) and the mile radius (transit supportive area) (RPG 2011). Figure 1-4 illustrates the transit core, the transit neighborhood, and the transit supportive area in a TOD.

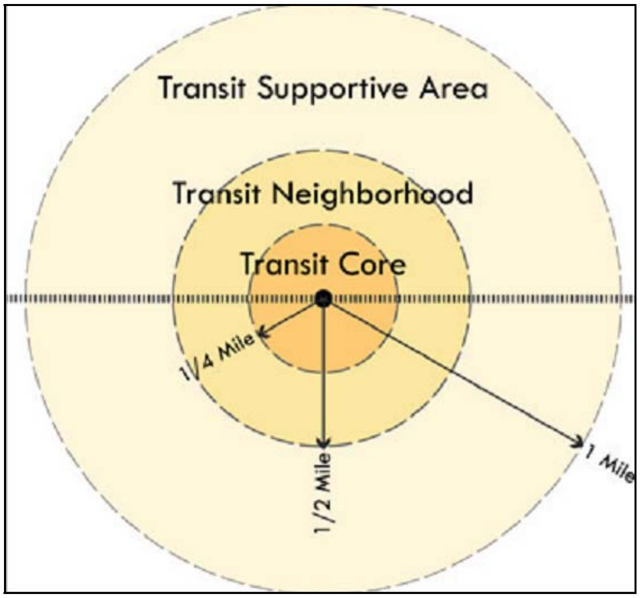

Figure 1-4. TOD areas (RPG 2011)

1.1.3 The Role of Transit as Part of Healthy Living

Litman (2010) indicates that public transit improvements and implementation of TOD can provide large but often overlooked health benefits. People who live or work in communities with quality public transportation tend to drive significantly less and rely more on alternative transportation modes (walking, cycling, and riding on public transit) than they would in more automobile-oriented areas. This approach reduces traffic crashes and pollution emissions; increases physical fitness and mental health; and supports active, healthy lifestyles. Such impacts are significant but often overlooked or undervalued in conventional transport planning studies. For example, the Federal Transit Administration’s (FTA) “New Starts” and “Small Starts” project evaluation framework considers public transit’s impact on congestion reductions, emission reductions, economic development impacts, and reductions in per-mile crash risks but generally ignores community-wide safety benefits, including reduced vehicle travel, air-quality improvements, and public-health benefits from increased walking and cycling activity (Litman 2010, FTA 2011). The contribution of transit availability and use in healthy communities is very important and may be a driving force to transform a community into a TOD one.

1.2 Study Objective

The objective of this study is to develop a better understanding of the economic impacts of transit availability. Specifically, the work involved will:

- Identify impacts of public-transit improvements and TOD and
- Quantify economic and health benefits of public-transit investment.

The study objectives will be accomplished through literature review and a case study.

The case study will demonstrate the costs and benefits from the introduction of new transit service in a Birmingham, Alabama community. Supporting infrastructure design changes will also be presented and considered to maximize access to public transportation and encourage transit ridership in mixed-use residential/commercial areas. Using appropriate analytical methods, the case study will quantify the economic costs and benefits from the introduction of transit within a TOD in the subject community.

Overall, the project aims at providing a framework for analyzing the economic benefits of investing in public transit at the national or local level and demonstrating the potential return from such investment.

1.3 Report Organization

This report is organized into five chapters:

- Chapter 1 discusses the scope and objectives of the research.
- Chapter 2 summarizes the review of literature related to TOD.
- Chapter 3 presents the study methodology and provides information on the case study and study approach.
- Chapter 4 discusses the analysis and summarizes the results obtained.
- Chapter 5 offers conclusions drawn from the results along with recommendations for future research.

Section 2
Literature Review

2.1 Introduction

TOD initiatives commonly covered in the literature focus on rail transit-oriented development (RTOD) with only a few TOD implementations focusing on bus transit-oriented development (BTOD). This chapter summarizes the design, development, and deployment attributes of BTOD and identifies the planning and operational strengths and challenges of BTOD.

2.2 Literature on BTOD and Deployment

BTOD has many key elements associated with planning, development, and deployment phases. The most important elements cited in the literature are summarized below.

2.2.1 Walking Distance and Accessibility

People are usually willing to walk up to 0.25 miles or 5 minutes to access a transit stop. Studies show a correlation between the distance from transit stops/stations and willingness to walk. For example, an on-board survey of transit users performed by Zhao, *et al*. (2003) revealed that most transit user trips to a transit stop were made within 1,800 feet of transit stops. As shown in Figure 2-1, a sharp drop in transit use occurred when the rider's origin was more than 0.06 miles (300 feet) from the stop and trip frequency diminished beyond 0.36 miles (1,900 feet) from a transit stop or station (Zhao, *et al*. 2003; Lam and Morrall 1982; Levinson and Brown-West 1984).

To estimate the potential number of transit users that a stop location may attract, the Geographic Information System (GIS) buffer zone tool may be used. The tool can identify how many people are within a certain distance (i.e. 0.25 miles) from transit stops/stations. But this method has some flaws in its assumptions. For example, population or employment are assumed to be evenly distributed across a zone and walking distances to access a transit service are considered the same as Euclidian distances (i.e. straight line or air distance), which is typically not the case. Furthermore, barriers either natural or man-made, such as limited-access highways, canals, community walls, and fences, can hinder accessibility but are not account for in the buffer zone method (Zhao, *et al*. 2003).

As an alternative, O'Neill, *et al*. (1995) proposed the network-ratio method based on the assumption that population density is the same along roads of the network. In this method, the travel distance is measured along streets. The ratio of total length of streets (within the 0.25-mile walking distance) to that of all the streets is used to identify the proportion of people within the transit service locality that could use the transit service. Hsiao, *et al*. (1997) implemented the above approach for the analysis of accessibility, transit usage, and transit users' demographics, and confirmed that higher accessibility areas provided higher transit usage.

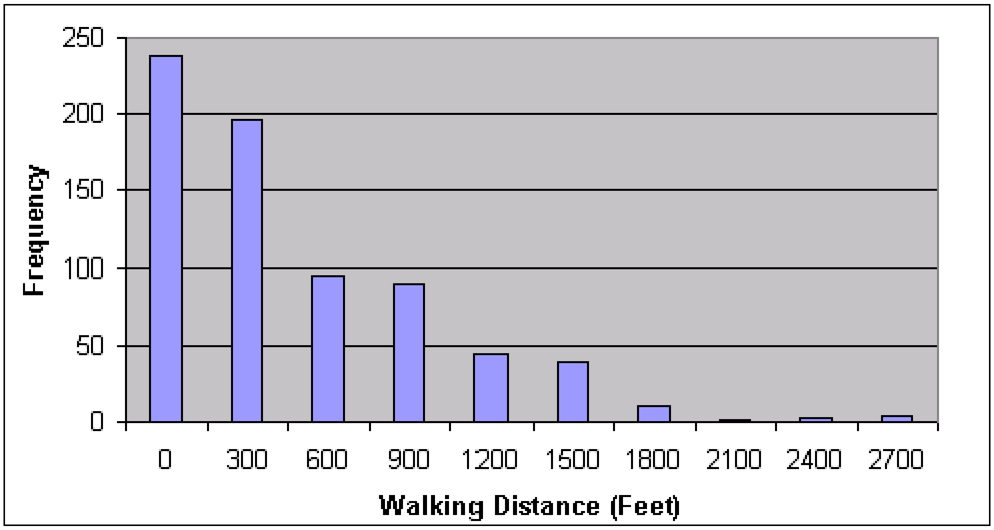

Figure 2-1. Frequency distribution of walking distances corresponding to transit trips (Zhao, *et al*. 2003)

An alternative approach discussed by Zhao, *et al*. (2003) identified transit accessibility for transit production trips with the consideration of walking distance to the transit stops, population density and distribution, and barriers to pedestrians. They show that the longer the walking distance, the lower the transit use is, and the relationship is exponential. So a decay function can represent the percentage of population served by transit.

Last but not least, an opinion survey performed by Olszewski and Wibowo (2005) revealed that the main factors that affect people's decision to walk to transit stations were walking distance, available provision of rain shelters, walking comfort, and security. Crowded walkways and the need to climb stairs were viewed unfavorably by the survey respondents.

2.2.2 Spatial and Temporal Transit Coverage

To serve as many origin-destination pairs as possible, bus transit systems often have complex networks. But complicated networks have the potential to hinder transit usage, so the literature suggests that less radial configurations and multifarious systems should be considered instead (Woyciechowicz and Shliselberg 2005). Also, circulator systems may be introduced to attract the choice riders (Cornillie 2008).

The literature review also points out that changes in service frequency have a larger effect on transit ridership than do changes in coverage. Radial transit plans and plans focused on multiple destinations differ in the use of the transfer, fare systems, and vehicle designs. Transit plans focused on multiple destinations have fewer routes focused on central business districts than radial plans. Route structures in multi-destination systems may follow a grid or spider-web pattern. The objective is to create lower peak-to-base ratios by encouraging more ridership outside of the peaks and on weekends providing a greater opportunity for transit dependent riders. Such systems allow users to reach more destinations that are important to them, such as large-volume, low-cost retail outlets; suburban service jobs; and medical facilities (Thompson and Brown 2006).

2.2.3 Planning and Deployment

Several factors affect transit performance (Kopp, *et al*. 2006) and user cost, and must be considered when planning or deploying a transit system. These factors include:

- Walk time at the stop/station
- Wait time for transit
- In-vehicle travel time
- Transfer time for transit and
- Travel cost (including fares, parking, and tolls)

The literature provides guidelines for proper planning and design, and examples from transit systems deployment efforts. For instance, the following characteristics have been used in the Dutch city of Utrecht (Nes 2003):

- Stop spacing = 350 meters
- Line spacing = 550 meters
- Frequency = 5 vehicles per hour
- Average travel distance = 3 kilometers
- Patronage of 100 travelers per square kilometer per hour

The decision variables are the stop spacing, line spacing, and the frequency, and are selected after considering local needs and priorities (Nes 2003).

2.2.3.1 Bus Running Ways Running ways can include mixed-traffic lanes, curb bus lanes, median bus ways, or designated bus-only lanes. Bus lanes are typically 11 to 12 feet wide. Shoulders are provided along the bus ways if space allows. For bus rapid transit (BRT), roadways are widened to about 50 feet at bus stations. The busway envelopes are 40 to 50 feet between stations and about 75 feet at stations consisting of four travel lanes and station platforms (Levinson, *et al*. 2003).

2.2.3.2 Stations and Bus Stops Bus and BRT station characteristics and features vary from system to system. The elements of a station include spacing, length, bypass capabilities, platform height, fare collection practices, and amenities. Stations can be located curbside, on the outside of bus-only lanes, or on center-island platforms. The length of the station depends on the type of buses operated and the frequency and is typically designed to accommodate two to three buses (four to five buses for busy stations) (Levinson, *et al*. 2003).

The spacing of stations ranges from 2,000 to 21,000 feet along freeways and bus ways, and from about 1,000 feet to over 4,000 feet along mixed-traffic arterial streets. The KFH Group (2009) recommends Metro bus service bus stops for the Washington Metropolitan Area Transit Authority be spaced as follows:

- Local Bus Service: 4-5 bus stops per mile,
- Enhanced Service/Limited Stop Service: 2-3 bus stops per mile, and
- Commuter/Express Stop Service: vary depending on major employment destinations and high boarding locations.

Ammons (2001) studied bus-stop spacing standards and estimated that the optimal bus-stop spacing typically ranges from 656–1,968 feet (200–600 meters) in urban areas, where most transit agencies consider 400 meters an acceptable access/egress standard. For BTOD, accessing a bus stop is considered to be achieved mainly by walking. According to Levinson, *et al*. (1992), walking about 400 meters is considerable based on an assumed average walking speed of about 1.3 meters/sec.

Bus-stop spacing, patronage, and service reliability are inherently linked. Studies show that passengers like to minimize in-vehicle and out-of-vehicle time (i.e. access, egress, and waiting times). Accessibility and service reliability with suitably spaced stops affect out-of-vehicle travel time, while service reliability is the major factor for in-vehicle travel time (El-Geneidy, *et al*. 2006). A monotonic increase between the density of stops and demand along a route and a monotonic decrease between the density of stops and the number of people on board have been observed (Vuchic and Newell 1968).

2.2.3.3 Bus Frequency Optimal transit service can be characterized by a limited number of stops, where there is high and predictable passenger activity and few service reliability problems. Table 2-1 illustrates recommended bus frequencies according to TOD type. It also provides the relationship between land-use mix and transit frequency (Strategic Economics 2009).

Table 2-1. Bus frequency according to TOD type

TOD Type	Land Use Mix	Typical Housing Density	Regional Connectivity	Frequencies
Urban Downtown	Office Center Urban Entertainment Multifamily Housing Retail	>60 units per acre	High Hub of Radial System	<10 minutes
Urban Neighborhood	Residential Retail Class B Commercial	>20 units per acre	Medium Access to downtown, sub regional circulation	10 minutes peak 20 minutes off-peak
Suburban Center	Primary Office Center Urban Entertainment Multifamily Housing Retail	>50 units per acre	High Access to downtown sub regional hub	10 minutes peak 10-15 minutes off-peak
Suburban Neighborhood	Residential Neighborhood Retail Local Office	>12 units per acre	Medium Access to suburban centers	20 minutes peak 30 minutes off-peak
Neighborhood Transit Zone	Residential Neighborhood Retail	>7 units per acre	Low Access to a Center	25-30 minutes Demand responsive

Source: EPA (2009)

2.2.3.4 Bus Travel Time For planning purposes, bus travel time must be considered. Hsu and Wu (43) proposed an equation to identify the round trip travel time of buses based on a number of parameter as show below:

$$T_r = 2\left\{\left(\frac{d}{v}\right) + \left[s\left(\frac{v}{2}\right)\left(\frac{1}{a}+\frac{1}{b}\right)\right] + \left(2\left(\frac{p}{m}\right)ht_p\right) + \left(\frac{t_t}{60}\right)\right\}$$

where:
T_r = round trip travel time (hr)
d = route length (miles)
v = travel speed (constant speed, mph)
s = number of stops and stations
p = passengers per hour per direction (pphpd)
t_t = layover and recovery time (min)
t_p = passenger boarding/alighting time (hr/passenger)
h = headway (hr)
m = number of buses per stop or station for BRT; LRT system m=1
a = acceleration rate (mph/hr)
b = deceleration rate (mph/hr)

The vehicle dwell time can be a substantial portion of travel time that impacts the service quality of a transit system (Daamen, *et al*. 2008). The *Highway Capacity Manual* (TRB 1998) defines bus dwell time as the total passenger boarding and alighting time plus the time required for opening and closing doors. According to Marshall, *et al*. (1990), bus configuration, maximum occupancy of the bus, total passengers boarding and alighting, stop density, and fare-collection procedures substantial affect the bus dwell time.

The *Highway Capacity Manual* (TRB 1998) also states that alighting and boarding times per passenger range from 1.5–6.0 and 1.5–8.0 seconds respectively and depend on the fare-collection procedure, baggage handling, and transfers. According to Levinson (1983), dwell time of buses ranges from 20–60 seconds in central business districts (CBD), 15 seconds in the city, and 10 seconds in suburban stops, depending on the city type, land use, and time of day. When determining vehicle dwell times, a common problem is the inability of electronic counters to distinguish between boarding and alighting passengers; thus, manual counting is used most of the time to improve accuracy (Kikuchi, *et al*. 2006).

As far as bus speed is concerned, the average bus speed is less than 20 mph on a mixed traffic right-of-way arterial street and 45–50 mph on an exclusive bus way (Hsu and Wu 2008). Beimborn, *et al*. (2003) noted that increasing bus speed is not as important to transit ridership as system connectivity and access. Another study found bus acceleration and deceleration peaks ranging from -6 to +4 mph/s due to frequent stop-and-goes at the bus stops, intersections, and bus terminals (Yoon, *et al*. 2005).

Actual bus travel time is important for transit users, but so is travel time reliability. Furth and Muller (2007) identified factors to improve bus-system reliability, such as scheduled departure times at terminals, time-points along the bus route, and early vehicle holds until the scheduled departure time. Headway variability can be lowered by real-time advanced vehicle location technology that can improve service reliability (Pangilinan, *et al*. 2008).

2.2.4 Affordability

Affordability refers to reduced financial burdens, particularly for lower-income households. Public transportation and TOD can increase affordability by reducing the need to own, operate, and maintain personal vehicles by providing affordable mobility for non-drivers and by reducing residential parking costs (Bell and Cohen 2009).

2.3 Methodologies for Measuring Economic Impacts of Transit Investment

Various methods exist to identify and measure the economic impacts of transit investments. The Transit Cooperative Research Program (Cambridge Systematics, *et al*. 1998) has listed twelve methods traditionally used for transit economic impact analysis. Some methods are employed for predictive studies, and some are for evaluative studies. Predictive economic impact models can forecast the likely economic impacts of a proposed transit investment, whereas evaluative models assess the effectiveness of economic investment post implementation. Some of the methods are quantitative and some are qualitative in nature. A brief summary of each method is presented next based on inputs from Cambridge Systematics, *et al*. (1998).

2.3.1 Regional Transportation-Land Use Models

As measured by travel demand models, improvements in transit system operations impact the overall system performance. Two changes can be measured, i.e., user benefits and non-user benefits. The traditional four-step travel demand model (i.e., trip generation, trip distribution, modal split, and trip assignment) can evaluate the impacts of a new transit system or a transit service expansion on network performance. Transit service chances will likely result in changes in travel patterns and behaviors which will, in turn, affect mode and route choice.

2.3.2 Benefit-Cost Analysis

Benefit-cost analysis (BCA) calculates and compares the benefits and costs of a project or government policy. To determine the benefit-cost (B/C) ratio, the benefits from implementing a project over a period of time (expressed in monetized values) are divided by the overall project costs (i.e. construction, operating, and maintenance costs), discounted with an appropriate discount rate to account for the time value of money. A B/C ratio greater than one implies that the benefits resulting from the project outweighs its costs. Due to future uncertainty, planners and decision makers rely on ratios higher than one to justify investments. BCA is usually used to forecast the likely economic impacts of a project as part of predictive studies.

2.3.3 Input-Output Models

In predictive studies, input-output (I-O) models depict the consequences of increased demand and consumption in a system. Regression equations link similar goods purchasing by different industrial sectors. Model inputs include total expenditure of an industry for construction, operation, and maintenance of a new transit system. Outputs from the model include total monetary value of direct, indirect, and induced production by the industry. The effects of travel cost reductions can also be traced by I-O models.

2.3.4 Economic Forecasting and Simulation Models

In economic forecasting and simulation models, inter-industry production-consumption functions of I-O models with additional elements identify the potential benefits from transportation investments. These models can differentiate between short-term investment impacts of constructing a system and long-term operation and maintenance impacts. They can also evaluate the effects of changes in transportation costs, land prices, and other factors in individual behavior. Stochastic simulations, regression equations, stepwise regression, and other statistical models are used in these models.

2.3.5 Multiple Regression and Econometric Models

Multiple regression and econometric models relate employment and land use with transit investment and transit-service levels. Multiple regression generally models the relationships between continuous variables. Hedonic price models and logistic regression analyze the economic impacts of transit investment. Hedonic Price Modeling attaches a monetary value to different attributes of a property. Logistic regression models are used when there are various multinomial or binomial variables and non-linear relationships between the dependent and independent variables. These models are generally used in evaluative studies.

2.3.6 Statistical and Non-Statistical Comparisons

Simple statistical comparisons can relate transit investments and economic activity and indicate any significant changes or differences through probabilities. Comparative analysis (non-statistical), using matched pairs, allows comparisons between an area containing the transit investment (study area) and an area with similar characteristics but without a transit system (control area) and analyzes both areas over time. This method is primarily used for evaluative studies.

2.3.7 Case Comparisons

Case comparisons can provide information on potential economic impacts from transit evaluations by reviewing the experiences of other cities with similar transit investments. Literature review and surveys of relevant stakeholders (planners, business people, transit agency representatives, etc.) can provide information on economic growth and development at the community level and the probable impact of similar investment in the study community. Case comparisons are used as part of predictive studies.

2.3.8 Interviews/Focus Groups/Surveys

Local factors are influential on the economic impacts of a transit investment. Local experts and leaders, businessmen, developers, community members, and the public can play an important role in assessing the overall economic impacts of transit investment through their opinions and experiences. Personal or telephone interviews with local experts can provide useful suggestions and valuable information about a past or ongoing project. Focus-group discussions facilitate exchanging of ideas of participants and can document perceptions, preferences, and priorities that may affect the transit investment. Surveys and the Delphi method can provide a base for the statistical analysis of collected information through a properly conducted survey and can be used for both predictive and evaluative studies.

2.3.9 Physical Conditions Analysis

Physical conditions analysis identifies the possible development opportunities within a proposed transit corridor relying on the availability of land and competitive market condition. One such method is a field survey, where the researcher checks land use and property maps, and verifies aerial photographs through direct observation. It can effectively assess an investment's development opportunities and constraints. This method can be used for both predictive and evaluative studies.

2.3.10 Real Estate Market Analysis

Real estate market analysis identifies the competitiveness of a corridor location, and the corridor's ability to support new development. Rent and land value premiums, low vacancy rates, rapid net absorption and land assembly within the corridor, and high market share capture rates are key factors that indicate positive impacts of transit investment. This method can be used for both predictive and evaluative studies.

2.3.11 Fiscal Impact Analysis

A fiscal impact analysis model can be used to find out the impacts of transit investment on government revenues and expenditures, including tax revenues. Future development, employment, income, sales, etc. are analyzed from the tax-revenues perspective. Gains in employment and income, as well as retail and real-estate sales, are expected to increase income and sales-tax revenues respectively. Fiscal-impact studies estimate likely investment revenues with construction, operation, and maintenance expenses. This method is primarily used for predictive studies.

2.3.12 Development Support Analysis

Development support analysis estimates the total square footage of development through improved transportation capacity due to a transit investment by measuring total additional trips accessing the study area without reducing the roadway level of service (LOS). This method relates physical conditions analysis, real-estate market analysis, and interviews with the analysis of growth constraints of highway capacity. Development-support analysis is typically used for predictive studies.

2.4 Literature on Health Impacts of BTOD

Physical activity provides proven health benefits. Many studies confirm that physical activity protects against heart disease, stroke, hypertension, type 2 diabetes, colon cancer, breast cancer, osteoporosis, obesity, depression, anxiety, and stress. According to a study in British Columbia, physical inactivity is responsible for 15% of heart disease, 19% of strokes, 10% of hypertension, 14% of colon cancer, 11% of breast cancer, 16% of type 2 diabetes, and 18% of osteoporosis cases (Colman and Walker 2004).

Earlier studies (Litman 2010, NCIPC 2010) identified eleven causes of potential years of life lost (i.e. estimation of the average years a person would have lived if there was not any premature death of that person). Transport activity affects five of these health risks to various extents: cancer, heart disease, motor vehicle crashes, congenital anomalies, and stroke. In 2007 the life expectancy for U.S. citizens was 78.1 years, which is about one year below the OECD average (79.0 years). Still, the U.S. spends $7,290 on healthcare per capita, which is two-and-a-half times greater than the OECD average (OECD 2011).

According to public-health researchers, providing sidewalks, improving transit systems, and increasing bike lanes encourages more physical activity. The literature states in the presence of a safe walking environment, 43% of people met recommended physical activity levels by walking within 10 minutes of home. Only 27% residents were physically active when the walking environment did not meet high standards.

Given the undeniable benefits of walking and bicycling and the fact that nearly 40% of all trips in the U.S. are two miles or less, a mode shift toward walking and biking appears feasible and desirable from transportation and health perspectives and can be accommodated within a complete-street design. The literature reports that 65% residents prefer to walk in a neighborhood using available sidewalks (NCSC 2011). Elements of a complete-street design to support active transportation choices include (Living Streets LA 2011):

- Bicycle lanes, paths and routes
- Bicycle lockers and racks
- Sidewalk treatments
- Sidewalk landscaping
- Curb extensions
- Crossing islands

- Vegetated medians
- Street furniture

The integration of public transit within a complete-streets community design significantly affects travel activity and serves the mobility, accessibility, and health needs of local residents. In fact, research indicates that the quality of public transit impacts the public health of a community, including overlooked or undervalued impacts (Litman 2010).

Improving transit services and designing or retrofitting a community as a transit-oriented development is expected to reduce driving and dependency on automobiles (Bailey, *et al*. 2008) and is expected to provide positive benefits to the individual and the community. In fact, public-transit users walk an average of 19 minutes daily, close to the recommended 22 daily minutes of moderate physical activity. U.S. citizens only walk 6 minutes a day on average (Besser and Dannenberg 2005, Weinstein and Schimek 2005).

Reducing premature deaths and disabilities caused by traffic accidents is another important concern. Annually, traffic accidents kill 40,000 people and cause even more significant injuries and disabilities (Litman 2010, RITA). In comparison, public transit is a relatively safe travel mode, accounting for only 1/20th the passenger fatality rate of automobile travel (Beck, *et al*. 2007). Moreover, analysis of crash records shows that the total per capita traffic fatalities (including transit riders, automobile drivers and passengers, and pedestrians combined) decline significantly as transit ridership increases in a community (Figure 2-2), another benefit from shifting automobile trips to transit.

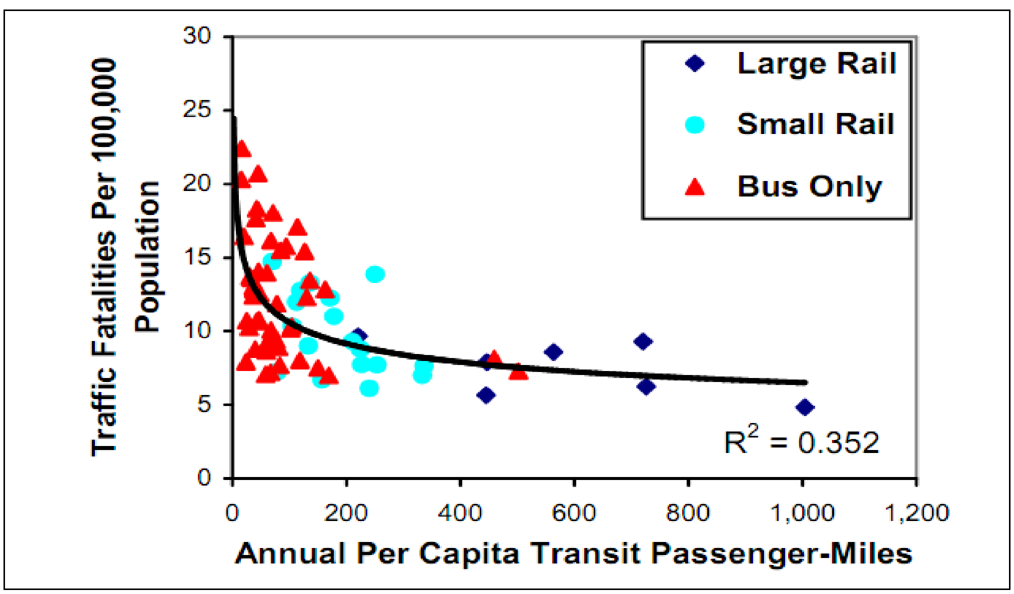

Figure 2-2. U.S. traffic deaths (Litman and Fitzroy 2012)

Vehicle emissions are another health-related concern. Many factors affect the impact of vehicle pollutants on human health. These factors include per capita vehicle mileage, vehicle-emission rates, and exposure (i.e. the number of people located where emissions are concentrated). Air pollution from motor vehicles causes a similar number of premature deaths as traffic crashes, though the victims of air pollution are disproportionately the older generation, which results in a smaller potential year of life lost compared to traffic crashes (Murray 1996).

Public transit tends to produce less pollution per passenger-mile, and several transit agencies include green bus options in their fleets, such as electric-powered, newer diesel vehicles, and CNG vehicles. Studies confirm that increased transit ridership and the introduction of TOD reduces per capita vehicle travel and associated emissions (Bailey, *et al*. 2008), as well as positively impacting public health.

2.4.1 Measuring Impacts of Alternative Transportations on Health

To measure related impacts, the Active Transport Quantification Tool (Thinking Transport 2010), which was developed through a partnership between ICLEI–Local Governments for Sustainability–Oceania (ICLEI Oceania) and the Victorian Health Promotion Foundation (Vic Health) in Australia, quantifies health, community, and environmental benefits of walking or bicycling. Also, the Land Transport New Zealand's *Economic Evaluation Manual* (New Zealand Transport Agency 2010) calculates the health benefits (in monetary value) of active transportation due to planning decisions that contribute to walking and bicycling activity.

Chenoweth and Bortz (2010) provide a web-based tool based on a scientific formula to quantify the economic costs of physical inactivity among U.S. citizens. The surgeon general defines physical inactivity "as less than 30 minutes of moderate physical activity most, if not all, days of the week" (Chenoweth and Bortz 2010). Based on the study methodology, the calculated cost of the physical inactivity can be obtained and is related to Medicare cost, worker's compensation, and lost productivity for a person per year.

Section 3
Case Study Methodology

3.1 Introduction

In the following sections a case study is used to demonstrate the potential impacts of transit expansion within a TOD complete-streets context. First, a study site is selected and data are gathered to establish current conditions and evaluate needs and opportunities for transit expansion. Then a plan is developed to redesign the transit system for the case study area to better serve local needs and increase transit ridership. In addition to determining bus-station locations, transit routes, and bus schedules, the plan also proposes design interventions for the promotion of easy access to the transit locations such as sidewalk enhancements and new bike routes. Next, a detailed benefit-cost analysis (BCA) is performed to evaluate the proposed transit system and to determine if the investment for the proposed transit improvements is justified. This is done by considering economic and health-related benefits resulting from the redesign of the transit operation at the study site and costs associated with the project including construction, operating, and maintenance costs. Finally, a sensitivity analysis is performed to gain insights on the likely net benefit-to-cost ratios that can be achieved for 5%, 10%, 15%, and 20% travel shifts from automobile to transit.

3.2 Study-Site Description

Fairfield, a city in Jefferson County, Alabama, has been selected as the case study. It is a part of the Birmingham–Hoover metropolitan area and is located approximately 10 miles west/southwest from downtown Birmingham. Based on the 2010 census, Fairfield has a population of 11,117. In 2009 the racial makeup of the city was 7.2% white; 91.1% black/African American; and 1.7% Hispanic, Latino, or other race.

In 2009 the estimated average household income in Fairfield was $34,456, or 17.5% lower than the state average ($40,489) (City-Data.com). Table 3-1 provides the income distribution in Fairfield. In 2000 about 16.5% of families and 21.5% of the population lived below the poverty line, including 27.7% of those under age 18 and 25.3% of age 65 or over.

The city's downtown area features a number of small, primarily service-related businesses and it is home to Miles College, a historically black college. Some retail businesses are concentrated along Aronov Drive, northwest of the Western Hills Mall. Certain parts of the Fairfield community are primarily residential with older residential developments at the north and central portions of the community and new residential developments located near the southwest.

Table 3-1. Annual income distribution in Fairfield

Annual Income ($)	Number of Households	% Households
< 10,000	376	8.4
10,000-15,000	540	12.1
15,000-20,000	531	11.9
20,000-25,000	291	6.5
25,000-30,000	183	4.1
30,000-35,000	312	7.0
35,000-40,000	163	3.6
40,000-45,000	352	7.9
45,000-50,000	175	3.9
50,000-60,000	267	6.0
60,000-75,000	497	11.1
75,000-100,000	471	10.5
100,000-125,000	82	1.8
125,000-150,000	154	3.4
150,000-200,000	66	1.5
> 200,000	10	0.2
Total	4470	100.0

Source: City-Data.com (2011)

The community is traversed by a major interstate highway (I-20/I-59) and state highway 11 and is currently serviced by one fixed transit route (Route 41-Fairfield), which is operated by the Birmingham-Jefferson County Transit Authority (BJCTA). As shown in Figure 3-1, transit Route 41 starts from the BJCTA central station in downtown Birmingham and terminates at the Walmart Super Center in Fairfield. There are three primary and several optional bus stops within the Fairfield boundary area along the existing transit route. BJCTA provides bus service from 5 am to 10 pm on weekdays and 6 am to 9 pm on Saturday. BJCTA does not provide bus service on Sunday. The detailed bus schedule is provided in Appendix A (Table A-1).

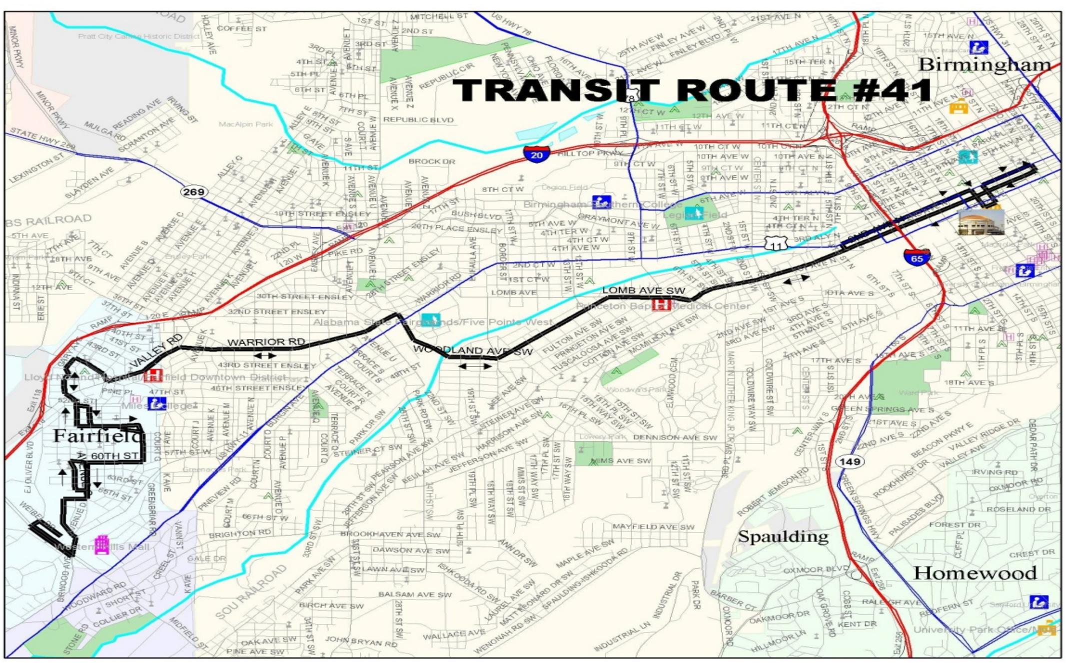

Figure 3-1. Transit Route 41 of BJCTA (BJCTA 2011)

Figure 3-2 details transit Route 41 within the Fairfield area. It should be noted that there is a newly developed residential zone in the southwest region of the city that is currently out of the reach of the present transit route.

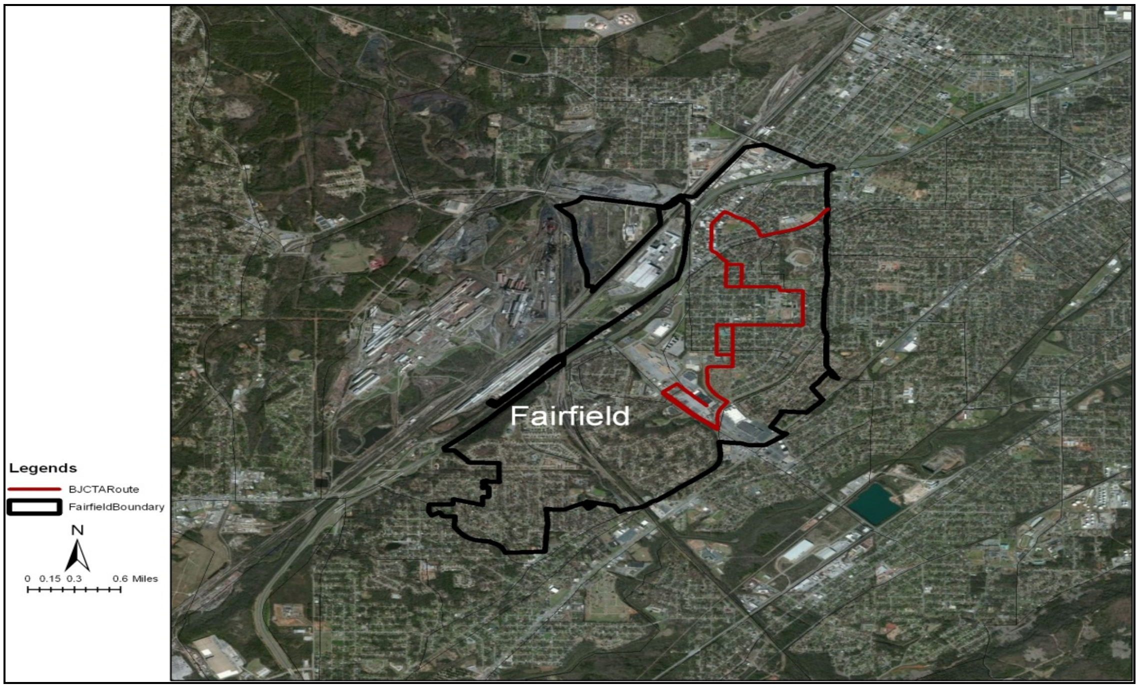

Figure 3-2. Transit Route 41 within Fairfield City

For analysis purposes, nine traffic analysis zones (TAZs) are considered within the Fairfield city limit. Figure 3-3 shows the population densities of these zones to help identify areas which can be considered for new transit service.

3.2.1 Present Transit Use

Passenger boarding and alighting data have been collected from the Birmingham-Jefferson County Transit Authority (BJCTA) and used to obtain information on the total present transit use. Tables 3.2, 3.3, 3.4, and 3.5 provide typical outbound (weekday), outbound (Saturday), inbound (weekday), and inbound (Saturday) ridership respectively within the Fairfield area. Table 3.6 summarizes all the outbound and inbound passenger data for easy reference.

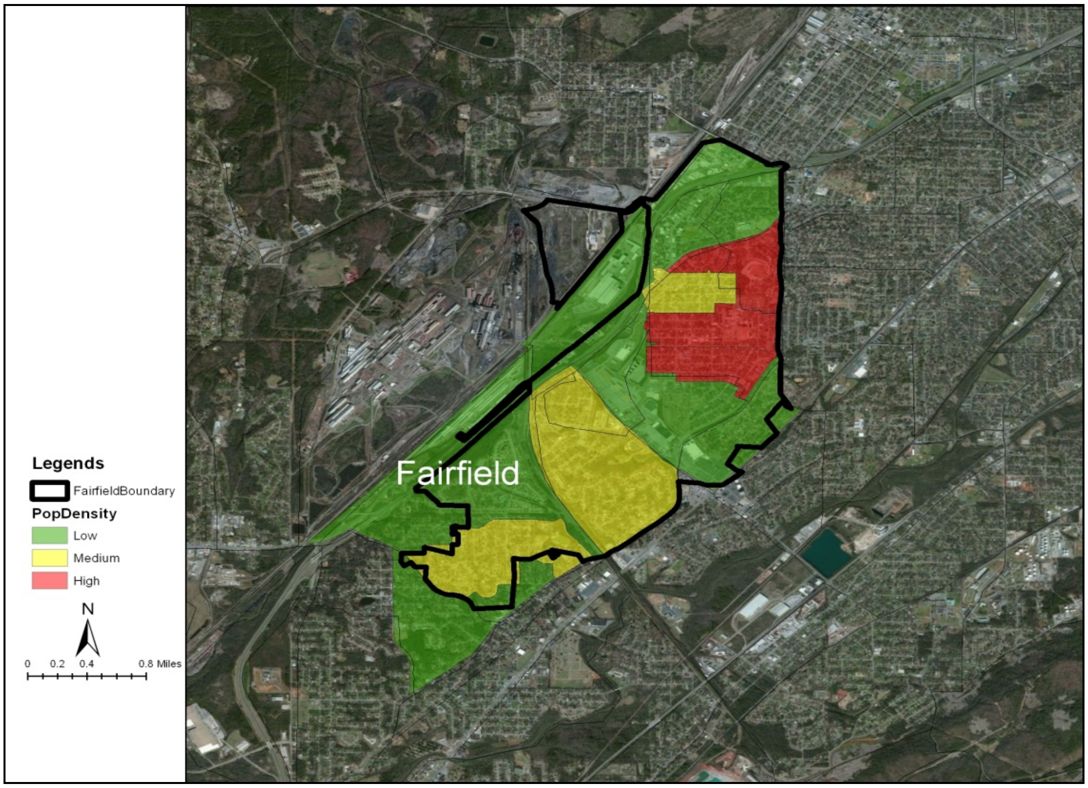

Figure 3-3. Population density within Fairfield City

Table 3-2. Outbound passenger boarding and alighting data on weekday

Location	Boarding	Alighting
Western Hill Mall Nearside Walmart	64	0
Terrace Ct Farside Ave D	2	0
Terrace Ct Nearside 6722 Address	0	0
Terrace Ct Nearside 66th St	2	1
66th St Nearside Ave C	4	2
Ave D Nearside 64th St	5	5
64th St Nearside Ave D	6	0
Ave C Nearside 62nd St	1	1
Ave C Nearside 60th St	2	3
60th St Nearside Court E	5	3
60th St Nearside Myron Massey Blvd	4	1
Myron Massey Blvd Nearside 55th Pl	0	0
Myron Massey Blvd Nearside 54th St	4	1
Myron Massey Blvd Nearside Ave F	1	0
55th St Nearside Ave D	3	1
55th St Nearside Ave C	7	0
Ave C Nearside 52nd St	5	2
Gary Ave Nearside 51st St	2	0
Gary Ave Nearside 49th St	3	0
Fairfield Park Nearside 45th St	10	1
Richard Scrushy Farside Valley Rd	2	2
Valley Rd Nearside Fairfield High School	2	24
Valley Rd Nearside 41st St	3	4
Total	**137**	**51**

Source: Birmingham-Jefferson County Transit Authority

Table 3-3. Outbound passenger boarding and alighting data on Saturday

Location	Boarding	Alighting
Western Hill Mall Nearside Walmart	50	0
Terrace Ct Farside Ave D	0	0
Terrace Ct Nearside 6722 Address	0	0
Terrace Ct Nearside 66th St	2	0
66th St Nearside Ave C	3	0
Ave D Nearside 64th St	1	0
64th St Nearside Ave D	0	0
Ave C Nearside 62nd St	3	2
Ave C Nearside 60th St	7	2
60th St Nearside Court E	3	2
60th St Nearside Myron Massey Blvd	1	0
Myron Massey Blvd Nearside 55th Pl	2	2
Myron Massey Blvd Nearside 54th St	2	1
Myron Massey Blvd Nearside Ave F	0	0
55th St Nearside Ave D	2	1
55th St Nearside Ave C	2	0
Ave C Nearside 52nd St	1	0
Gary Ave Nearside 51st St	0	1
Gary Ave Nearside 49th St	2	1
Fairfield Park Nearside 45th St	6	0
Richard Scrushy Farside Valley Rd	1	1
Valley Rd Nearside Fairfield High School	2	0
Valley Rd Nearside 41st St	1	1
Total	**91**	**14**

Source: Birmingham-Jefferson County Transit Authority

Table 3-4. Inbound passenger boarding and alighting data on weekday

Location	Boarding	Alighting
Valley Road Nearside 41st St	6	5
Valley Road Nearside Lloyd Noland	2	5
Valley Road Nearside Richard Scrushy Pkwy	1	1
Richard Scrushy Pkwy Nearside Post Office	6	10
Richard Scrushy Pkwy Nearside 45th St	0	0
Gary Ave Nearside 47th St	0	6
Gary Ave Nearside 49th St	0	6
Ave C Nearside 52nd St	0	11
52nd St Nearside Ave D	0	3
Ave D Nearside 54th St	0	1
Ave E Nearside 54th St	0	3
55th St Nearside Ave E	3	0
Myron Massey Blvd Nearside 55th Pl	1	3
Myron Massey Blvd Far side 54th St	2	5
Myron Massey Blvd Nearside 60th St	1	1
60th St Nearside Ave F	0	1
60th St Nearside Court E	2	1
60th St Nearside Ave D	6	5
Ave D Nearside 62nd St	0	0
Ave D Nearside 64th St	3	5
Ave D Nearside 66th St	4	4
66th St Nearside Ave C	0	4
Terrace Ct Nearside 67th St	2	10
Terrace Ct Nearside MLK Dr	1	34
Aaron Aronov Dr Nearside Pizza Hut	0	4
Aaron Aronov Dr Nearside Shell Service	2	11
E.J. Oliver Blvd Nearside 64th St	0	3
64th St Nearside Bellview Plaza	13	8
Western Hill Mall Nearside Walmart	0	14
Total	**55**	**164**

Source: Birmingham-Jefferson County Transit Authority

Table 3-5. Inbound passenger boarding and alighting data on Saturday

Location	Boarding	Alighting
Valley Road Nearside 41st St	2	4
Valley Road Nearside Lloyd Noland	0	4
Valley Road Nearside Richard Scrushy Pkwy	1	1
Richard Scrushy Pkwy Nearside Post Office	0	2
Richard Scrushy Pkwy Nearside 45th St	0	1
Gary Ave Nearside 47th St	0	1
Gary Ave Nearside 49th St	1	0
Ave C Nearside 52nd St	0	1
52nd St Nearside Ave D	0	3
Ave D Nearside 54th St	0	2
Ave E Nearside 54th St	1	1
55th St Nearside Ave E	0	1
Myron Massey Blvd Nearside 55th Pl	0	1
Myron Massey Blvd Farside 54th St	3	4
Myron Massey Blvd Nearside 60th St	0	1
60th St Nearside Ave F	0	1
60th St Nearside Court E	1	0
60th St Nearside Ave D	1	1
Ave D Nearside 62nd St	2	1
Ave D Nearside 64th St	0	0
Ave D Nearside 66th St	0	5
66th St Nearside Ave C	0	2
Terrace Ct Nearside 67th St	1	5
Terrace Ct Nearside MLK Dr	0	10
Aaron Aronov Dr Nearside Pizza Hut	0	8
Aaron Aronov Dr Nearside Shell Service	2	1
E.J. Oliver Blvd Nearside 64th St	0	3
64th St Nearside Bellview Plaza	0	0
Western Hill Mall Nearside Walmart	0	28
Total	**15**	**92**

Source: Birmingham-Jefferson County Transit Authority

Table 3-6. Total passenger boarding and alighting data on weekday and Saturday

Day of Week	Outbound		Inbound	
	Boarding	Alighting	Boarding	Alighting
Weekday	137	51	55	164
Saturday	91	14	15	92

Source: Birmingham-Jefferson County Transit Authority

Based on the current ridership data presented above, the internal transit trips have been found to be 106 (51 + 55) trips on weekdays and 29 (14 + 15) trips on Saturdays. The total external trips have been calculated to be 195 [(137 - 51) + (164 - 55)] trips on weekdays and 154 [(91 - 14) + (92 - 15)] trips on Saturdays.

3.2.2 *Identification of Transit Trips Attractions Zones*

Current automobile origin-destination (O-D) data have been collected from the Regional Planning Commission of Greater Birmingham (RPCGB) and used to identify employment zones. This information is used to determine potential destination zones for transit users. The total automobile trips to all TAZs outside the Fairfield area have been calculated to identify the TAZs that attract higher number of automobile trips from Fairfield. Table 3-7 provides the total automobile trips to some of the higher attraction zones outside the Fairfield area. Three zones (i.e. TAZ 444, 664, and 666) have been identified as employment zones, as these zones solely consist of commercial- or business-land use. TAZ 388, 400, 403, 611, 399, etc. are not analyzed as they are residential areas.

Table 3-7. Total daily trips to the higher attraction zones outside Fairfield

TAZ	388	400	**664**	**444**	**666**	403	611	399
Total Daily Trips to TAZ	518	466	**335**	**288**	**275**	274	265	264

Source: Trip Data from Regional Planning Commission of Greater Birmingham

3.2.3 *Current Automobile Trips to Attraction Zones*

Automobile O-D data were used to identify total automobile trips to the selected attraction zones under current conditions. Tables 3-8 and 3-9 provide the Fairfield automobile trips per day to and from TAZ 444 considering also TAZ 383, 388, 400, and 403 trips. These zones are along the proposed bus route and attract more than 200 trips per day from Fairfield. Moreover, TAZ 402 was included as it is located in between of other high trip-attraction zones. A total of 1,932 automobile trips are being made between Fairfield and the above mentioned TAZ.

Tables 3-10 and 3-11 provide the automobile trips per day to TAZ 664 and 666 as well as TAZ 399, 613, 616, and 615. TAZs 399, 613, and 616 are located along the proposed bus route and attract more than 200 trips per day, whereas TAZ 615 is considered due to its proximity to TAZ 613 and 616. A total of 1,398 automobile trips are being made to and from Fairfield and the above mentioned TAZ.

Table 3-8. Automobile trips to TAZ 444 from Fairfield considering other TAZs along the route (RPCGB)

TAZ	383	388	400	402	403	444	Total
389	11.62	8.71	5.33	4.79	7.52	5.21	43
390	12.88	10.85	7.56	5.65	8.61	7.32	53
391	20.92	239.41	22.96	14.46	32.62	31.96	362
392	6.07	4.47	4.32	2.34	4.58	5.87	28
393	23.27	35.04	257.12	20.55	33.25	27.27	397
394	31.48	61.14	37.57	24.53	47.66	38.88	241
395	20.63	30.79	20.08	16.9	23.29	16.68	128
396	50.05	43.29	20.56	16.53	37.74	20.28	188
397	16.24	23.91	18.17	12.36	19.56	20.09	110
398	15.64	25.19	26.37	13.96	22.85	32.88	137
610	23.75	35.22	45.9	21.18	36.38	81.32	244
Total	232.55	518.02	465.94	153.25	274.06	287.76	1,932

Table 3-9. Automobile trips from TAZ 444 to Fairfield considering other TAZs along the route

TAZ	389	390	391	392	393	394	395	396	397	398	610	Total
383	11.62	12.88	20.92	6.07	23.27	31.48	20.63	50.05	16.24	15.64	23.75	236
388	8.71	10.85	239.41	4.47	35.04	61.14	30.79	43.29	23.91	25.19	35.22	518
400	5.33	7.56	22.96	4.32	257.12	37.57	20.08	20.56	18.17	26.37	45.90	466
402	4.79	5.65	14.46	2.34	20.55	24.53	16.90	16.53	12.36	13.96	21.18	153
403	7.52	8.61	32.62	4.58	33.25	47.66	23.29	37.74	19.56	22.85	36.38	274
444	5.21	7.32	31.96	5.87	27.27	38.88	16.68	20.28	20.09	32.88	81.32	2876
Total	43.18	52.87	362.33	27.65	396.5	241.26	128.37	188.45	110.33	136.89	243.75	1,932

Source: Regional Planning Commission of Greater Birmingham

Table 3-10. Automobile trips to TAZ 664 and 666 from Fairfield considering other TAZs along the route

TAZ	399	613	615	616	666	664	Total
389	5.46	4.48	2.16	5.57	5.83	7.67	31
390	7.27	6.45	2.78	7.2	8.3	12.11	44
391	21.67	18.5	6.69	17.75	24.7	26.48	116
392	4.04	3.4	1.11	3.12	5.44	7.18	24
393	57.28	23.45	8.69	25.07	26.82	31.08	172
394	34.88	33.42	15	34.8	35.59	44.7	198
395	19.47	16.9	6.58	19.73	17.57	24.15	104
396	20.37	25.08	19.81	30.74	22.31	36.75	155
397	17.43	15.26	6.18	16.02	18.22	22.87	96
398	25.6	20.57	5.87	18.41	31.14	31.75	133
610	50.46	50.83	11.93	40.76	78.56	90.09	323
Total	263.93	218.34	86.8	219.17	274.48	334.83	1,398

Source: Regional Planning Commission of Greater Birmingham

Table 3-11. Automobile trips from TAZ 664 and 666 to Fairfield considering other TAZs along the route

TAZ	389	390	391	392	393	394	395	396	397	398	610	Total
399	5.46	7.27	21.67	4.04	57.28	34.88	19.47	20.37	17.43	25.6	50.46	264
613	4.48	6.45	18.5	3.4	23.45	33.42	16.9	25.08	15.26	20.57	50.83	218
615	2.16	2.78	6.69	1.11	8.69	15	6.58	19.81	6.18	5.87	11.93	87
616	5.57	7.2	17.75	3.12	25.07	34.8	19.73	30.74	16.02	18.41	40.76	219
664	7.67	12.11	26.48	7.18	31.08	44.7	24.15	36.75	22.87	31.75	90.09	335
666	5.83	8.3	24.7	5.44	26.82	35.59	17.57	22.31	18.22	31.14	78.56	274
Total	31.17	44.11	115.79	24.29	172.39	198.39	104.4	155.06	95.98	133.34	322.63	1,398

Source: Regional Planning Commission of Greater Birmingham

Table 3-12 provides the total automobile trips within Fairfield area per day. About 3,900 automobile trips are made internally by the locals for various purposes.

Table 3-12. Internal automobile trips within Fairfield area

TAZ	389	390	391	392	393	394	395	396	397	398	610	Total
389	0	30	8	25	5	8	5	61	6	8	13	169
390	30	0	9	15	7	12	7	89	7	9	15	200
391	8	9	0	5	22	267	19	42	17	19	27	435
392	25	15	5	0	5	8	5	13	4	4	6	90
393	5	7	22	5	0	36	18	20	17	26	44	200
394	8	12	267	8	36	0	61	42	103	206	55	798
395	5	7	19	5	18	61	0	18	146	75	41	395
396	61	89	42	13	20	42	18	0	26	29	44	384
397	6	7	17	4	17	103	146	26	0	84	28	438
398	8	9	18	4	26	206	75	29	84	0	30	489
610	13	15	27	6	44	55	41	44	28	30	0	303
Total	169	200	434	90	200	798	395	384	438	490	303	3,901

Source: Regional Planning Commission of Greater Birmingham

3.2.4 Local Area Considerations

RPCGB has developed the Regional Transportation Plan (RTP), which proposes several transit projects in the region and related improvements (RPCGB "Transit"). Among those, the Southwest Corridor Transit Study includes transit development in Bessemer and Hueytown through Highway 11, which passes by the side of the Fairfield community. The objective is to improve transit services along the Bessemer Superhighway Corridor and encourage "smarter" and greener planning and land use to improve daily travel conditions and the quality of life of local residents and to energize economic development by attracting new housing, jobs, and services (RPCGB *Southwest Corridor Transit Study*).

The current proposed plan and frequency of transit deployment of RPCGB of the southwest corridor are shown in Figure 3-4 and Table 3-13 respectively. The plan of transit service expansion in Fairfield proposed in this project works synergistically with the RPCGB plans for regional transit network development. Implementation of the case study plan proposed in Section 3.3 can play an important role in providing useful connectivity and transfer of passengers to the proposed regional transit network in the future.

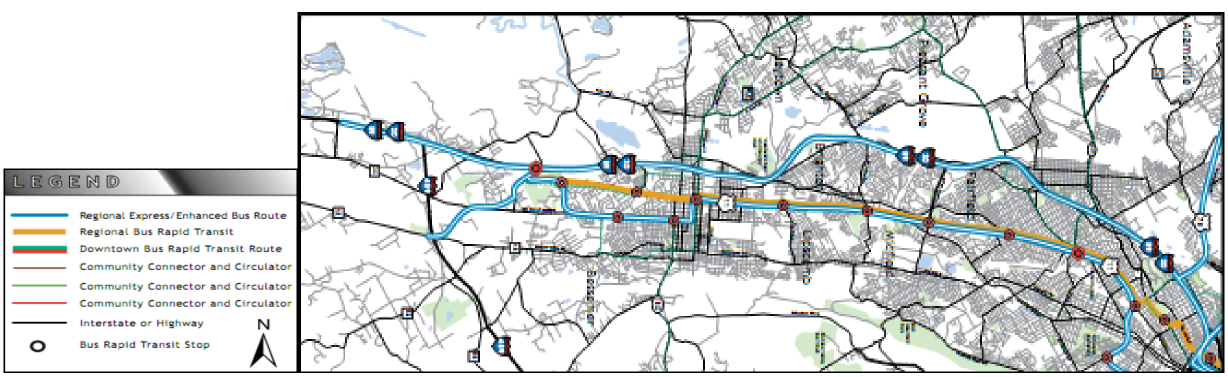

Figure 3-4. Proposed southwest corridor transit improvement plan from RPCGB (2009)

Table 3-13. Frequency of transit deployment in proposed southwest corridor improvement plan from RPCGB

<table>
<tr><th colspan="5">Southwest Corridor</th></tr>
<tr><th rowspan="2">Type of Service</th><th rowspan="2">Service Location</th><th rowspan="2">Frequency Peak/Off-Peak</th><th colspan="2">Total Cost</th></tr>
<tr><th>Capital</th><th>Operating/Year</th></tr>
<tr><td rowspan="3">Express/Enhanced Bus Services</td><td>Bessemer Express (I-59)</td><td>20/0 minutes</td><td rowspan="2">$140,025,592</td><td rowspan="2">$6,947,700</td></tr>
<tr><td>Bessemer – Bus Rapid Transit</td><td rowspan="2">10/20 minutes</td></tr>
<tr><td>Bessemer – Eastern Valley Enhanced Bus</td><td>$8,967,650</td><td>$6,481,550</td></tr>
<tr><td rowspan="4">Community Bus Services</td><td>Bessemer Circulator</td><td rowspan="4">20/40 minutes</td><td rowspan="4">$8,967,650</td><td rowspan="4">$6,481,550</td></tr>
<tr><td>Hueytown – Pleasant Grove Circulator</td></tr>
<tr><td>5-Points W Ensley to Hueytown Connector</td></tr>
<tr><td>Highway 150 Cross Town Connector</td></tr>
<tr><td colspan="3">Total</td><td>$148,993, 242</td><td>$13,429,250</td></tr>
<tr><td></td><th>Location</th><th>Parking spaces</th><td colspan="2"></td></tr>
<tr><td>Park and Ride Lots</td><td>Hueytown Baptist Church</td><td>36</td><td colspan="2"></td></tr>
<tr><td></td><td>Total</td><td>36</td><td colspan="2">13 – Stations/Enhanced Stops</td></tr>
</table>

Source: RPCGB (2009)

3.2.5 Traffic Safety Considerations

Traffic accident records were obtained from the Center for Advanced Public Safety (CAPS) crash database (CAPS "Downloads") for the Fairfield city area. According to 2010 data, there were 285 traffic crashes in the study area involving 432 vehicles. These crashes resulted in 2 fatalities, 18 major injuries, and 56 minor injuries (Table 3-14).

Table 3-14. Traffic accident records within Fairfield in 2010

Collisions	Type of Collision				
	Property Damage Only	Minor Injury	Major Injury	Fatal	Total
Crashes	221	48	14	2	285
Vehicles Involved	432	91	24	3	550
Persons Involved	618	56	18	2	694

Source: CAPS (2011)

3.3 Proposed Transit Improvement Plan

3.3.1 Background

The existing transit system only serves half of the Fairfield area and a large newly growing portion is out of reach of the transit facility. Furthermore, the transit system only connects the community to the Central Station located in downtown Birmingham.

To better serve work-related and internal trips, existing transit routes in the study area need to be redesigned. For this purpose, under the new transit plan, the primary employment zones for Fairfield are considered transit trip destinations. The introduction of new extensive transit service is expected to result in a 10% travel mode shift from automobile to transit. Based on this assumption, future transit trips are calculated to obtain the bus frequency and to determine the number of bus trips required to serve the projected transit demand. Finally, additional engineering improvements are proposed to create a TOD buffer zone around the new transit routes and to further support the transit improvement plan. The details are summarized in the following paragraphs.

3.3.2 New Local Station Location and Transit Routes

The current transit routes are to be modified to better serve the work-related trips to attraction zones (i.e. employment zones TAZ 444, 664, and 666 and other TAZ attracting over 200 trips/day) and Fairfield community internal trips. Figure 3-5 shows currently operating transit Routes 41 and 45 (Route 45 operates to Bessemer) and the three work-trip attraction zones in the study area. As part of the new transit improvement plan, a local station is proposed at the center of the study area on an approximately 20,000 square foot piece of open land opposite the Walmart Super Center. The local station will allow transfers to maintain Fairfield's connectivity to Central Station and provide parking places for buses, monthly or special ticket sales to transit passengers, information on transit services, passenger waiting areas, etc.

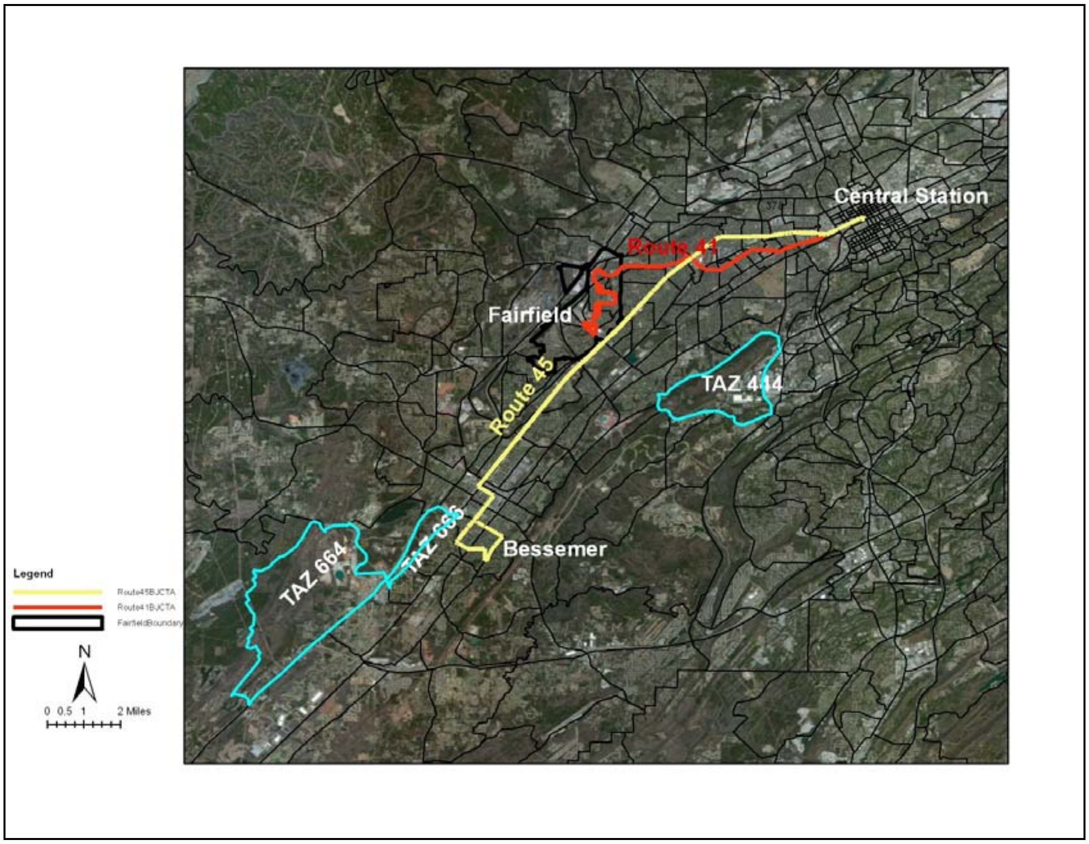

Figure 3-5. Current transit routes of BJCTA and identified employment zones

Moreover, as Figure 3-6 illustrates, three new transit routes are considered in the transit-redesign plan. The proposed routes are Route 664 serving TAZ 666 and 664, Route 444 covering TAZ 444, and an internal route serving the needs of the residents of Fairfield. For ease of accessibility, bus stops are recommended every 400 meters (0.25 miles) within the city limits and external attraction TAZs.

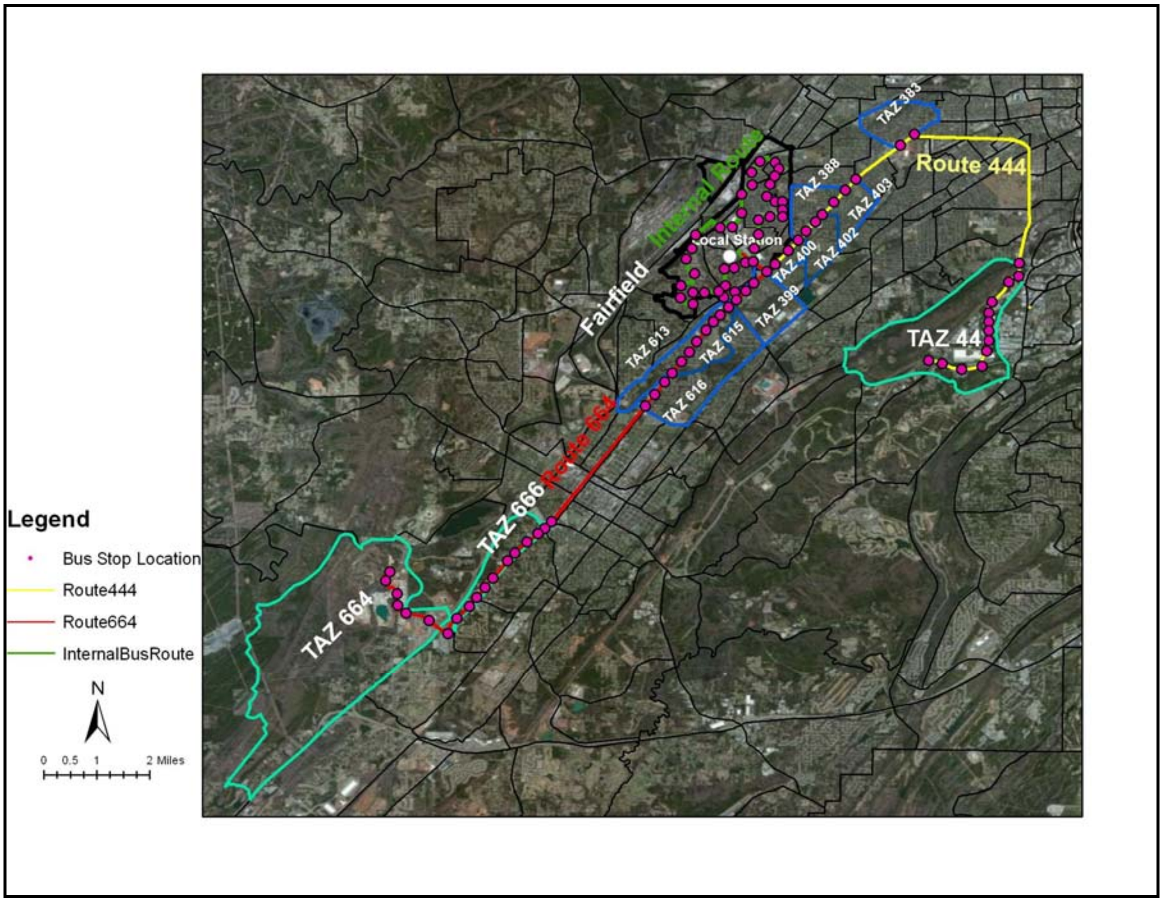

Figure 3-6. Local station and proposed transit routes

3.3.3 Additional TOD-related Proposed Improvements

To increase access to the local station and bus stops within the Fairfield area, further design improvements are desirable. A quarter-mile buffer around the internal bus route and local station is considered for the identification of locations to be further developed for the promotion of walking and bicycling and easy access to the transit locations. The buffer zone (see Figure 3-7) incorporates nearly the entire Fairfield city area. Therefore, development planning for the whole city is considered.

One of the enhancements considered as part of the transit improvement plan includes introducing bike lanes along designated bike routes with consideration of shared lanes for increasing connectivity and access to transit and improving sidewalks for pedestrian use. Other improvements—such as bicycle lockers and racks, sidewalk landscaping, streetscape, and crossing islands—are also considered to encourage non-motorized travel and integrate the new transit routes into a complete-streets design.

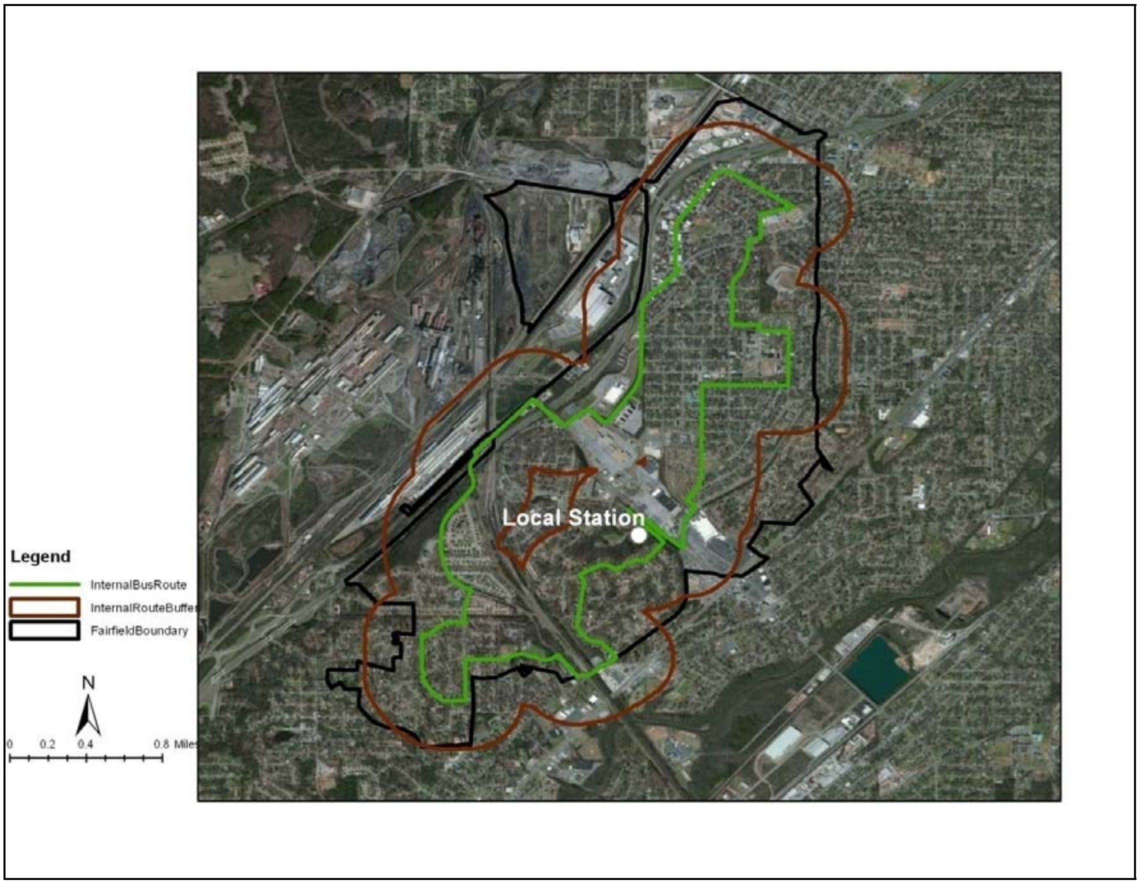

Figure 3-7. Buffer zone around the proposed local station and internal bus route

After taking into account geometric design considerations, transit access points, safety considerations and local needs, proposed bike routes are selected as illustrated in Figure 3-8. Schools, places of worship, and parks were given priority when providing bicycle lanes. The bicycle lanes (shared or exclusive on street) are mostly provided on the roads with a 35 mph speed limit.

To improve walkability, accessibility to transit stops, and pedestrian safety, adequate and well maintained sidewalks are needed. Most of the northern part of the city has sidewalks of about 4-5 feet. The southwestern portion of the city is newly developed and the roads are without sidewalks. Presently, about 192,047 feet (approximately 36.5 miles) of 370,249 feet of roadways are without sidewalks, hindering the safe, efficient movement of pedestrian transportation system users. To improve the situation, Figure 3-9 illustrates the proposed additional sidewalks for Fairfield that are expected to further support the transit improvement by enhancing accessibility to transit.

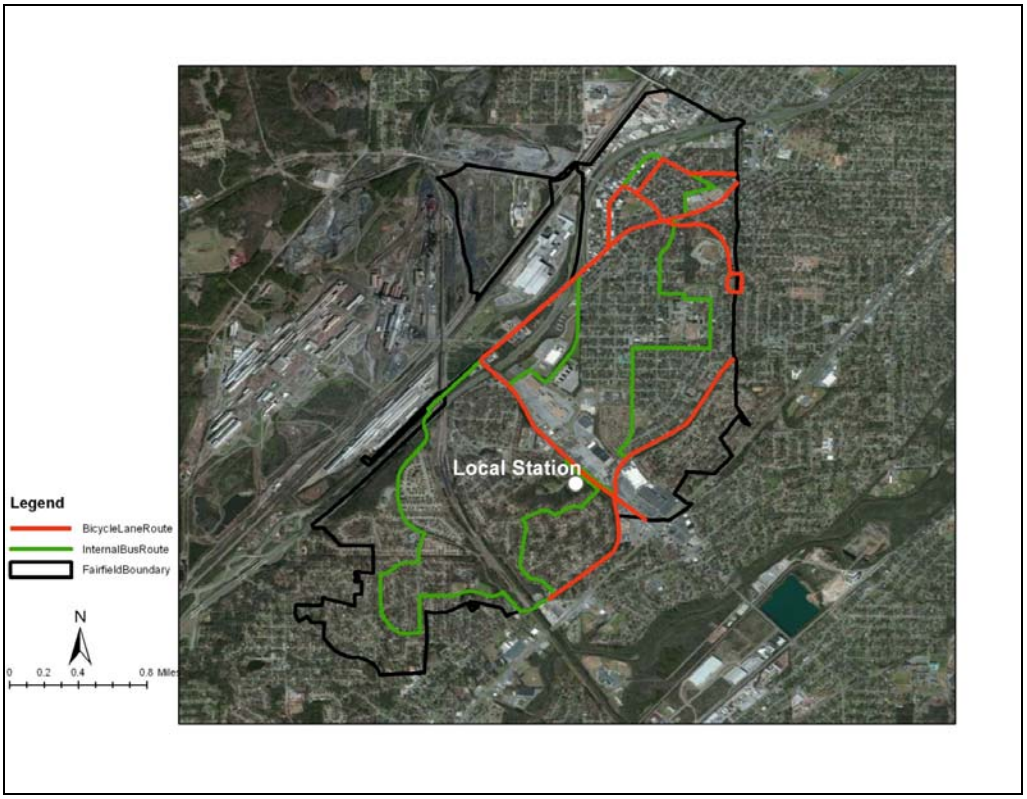

Figure 3-8. Proposed on-street bike routes for Fairfield

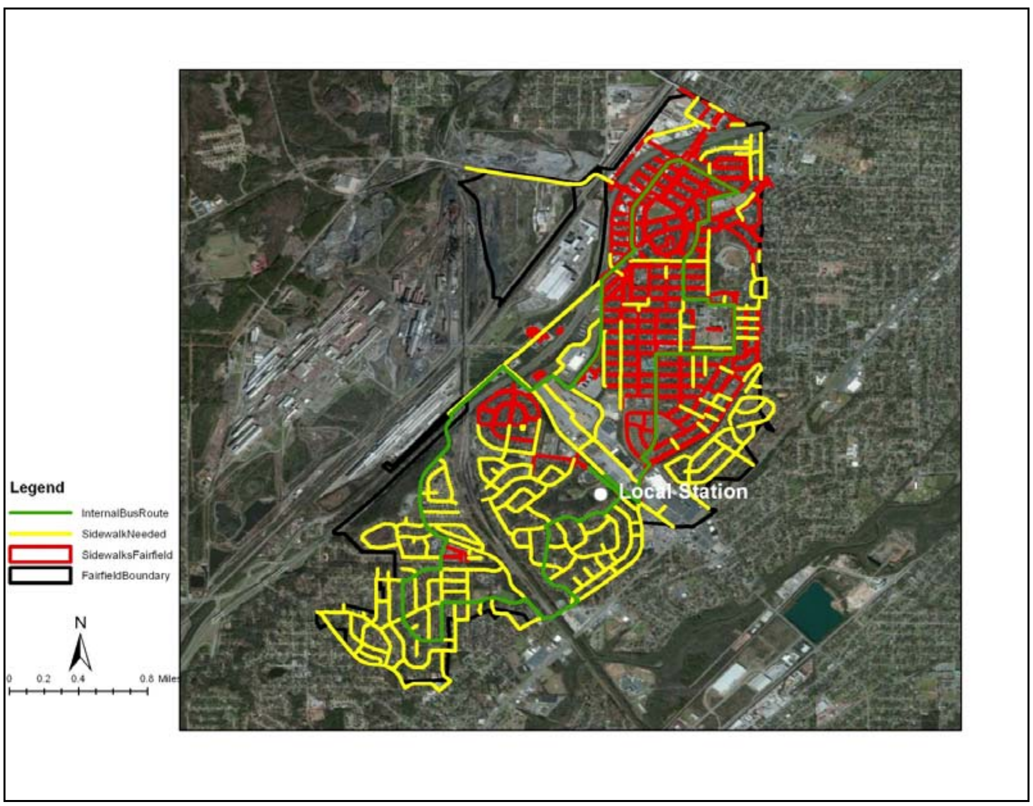

Figure 3-9. Existing and proposed sidewalks for Fairfield (RPCGB)

The blue lines in Figure 3-10 show the local roads that will connect the proposed local station with the Aaron Aronov Drive. The red lines show the provision of pedestrian and bicycle crossings near the transit station.

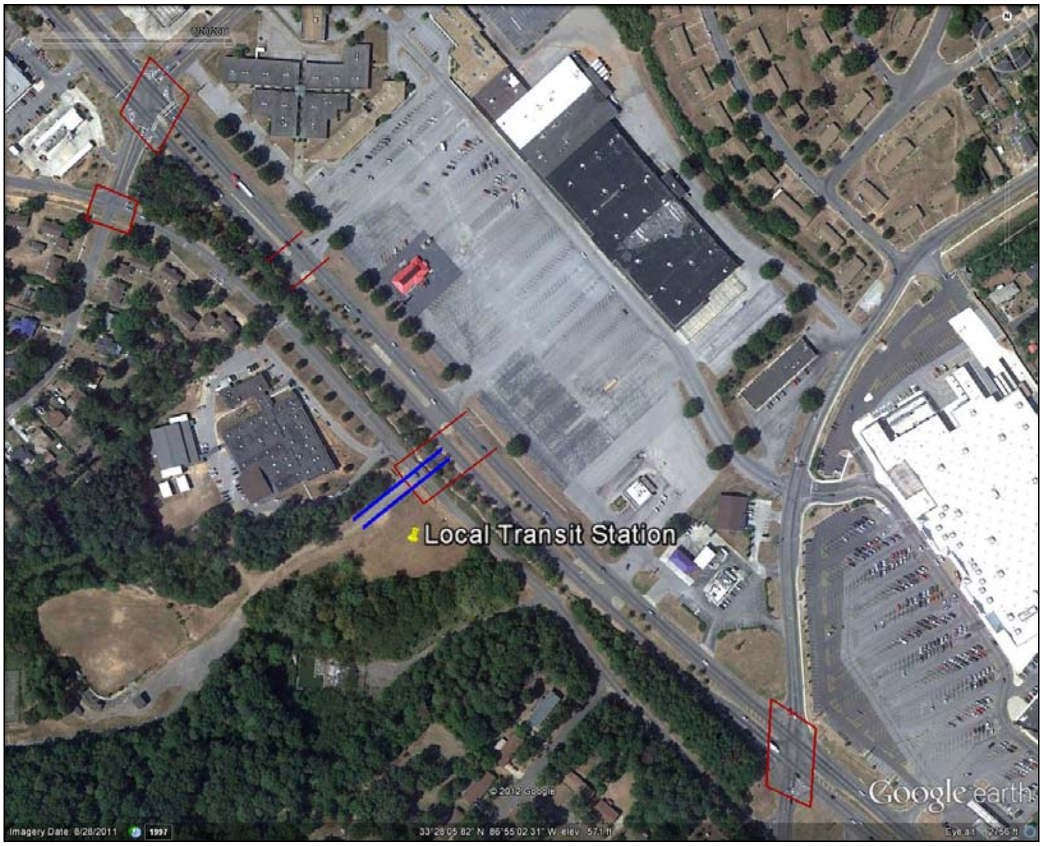

Figure 3-10. Proposed local station and connection to Aaron Aronov Drive (Google Earth)

3.3.4 Estimation of Future Transit Use

Table 3-15 provides information on the future transit use assuming 10% of trips shift from automobile to transit and after considering current O-D trips to transit attraction zones (see Tables 3-8, 3-9, and 3-10) and present transit use.

Table 3.15. Future transit use due to the proposed transit system

<table>
<tr><th>TAZ</th><th>Total Trips</th><th>10% Shift to Transit</th><th>Transit Trips</th><th>Present Transit Use</th><th>Future Transit Use</th><th>Comments</th></tr>
<tr><td>444</td><td>3,864</td><td>387</td><td rowspan="3">667</td><td rowspan="3">195 (towards downtown Birmingham)</td><td rowspan="3">667+195=862</td><td rowspan="3">External Trips</td></tr>
<tr><td>664</td><td rowspan="2">2,796</td><td rowspan="2">280</td></tr>
<tr><td>666</td></tr>
<tr><td>Internal</td><td>3,901</td><td>390</td><td>390</td><td>106</td><td>390+106=496</td><td>Internal Trips</td></tr>
</table>

3.3.5 Calculation of Round Trip Bus Travel Time and Bus Frequency

The calculation of round trip bus travel time for the proposed bus routes is based on the equation proposed by Hsu and Wu (2008) listed in Section 2.2.3.4. According to Hsu and Wu, bus speed is typically less than 20 mph on a mixed traffic right-of-way arterial street and average acceleration and deceleration rates are 5 mph/s and 7 mph/s as recommended in the literature (Yoon, *et al*. 2005). Layover and recovery time is considered 3 minutes, average bus-stop spacing is considered 400 meters (0.25 miles) (Levinson 1992), and average passenger boarding/alighting time is assumed to be 4 seconds per passenger (TRB 1998).

At the study site there are 4,943 houses, 4,586 of which are occupied (2,863 owner occupied and 1,723 renter occupied). The total area of Fairfield is 3.5 square miles (2,240 acres) (City-Data 2011). Thus the housing density for Fairfield is 2.21 units per acre. According to Strategic Economics' recommendations (Strategic Economics), the TOD strategy for Fairfield is a neighborhood transit type and transit frequency should be 25-30 minutes for this type of TOD.

BJCTA operates CNG buses due to the agency's commitment to air quality and pollution control. In 2009 BJCTA officials reaffirmed this commitment by stating that "the BJCTA intends to purchase only CNG vehicles when future purchases are made" (Bentley 2009). In 2009 BJCTA purchased CNG-powered North American Bus Industries (NABI) LFW model buses equipped with wheelchair ramps, security cameras, audible announcement systems, and bicycle racks (NABI 2009). For the analysis in this study, the NABI 40-LFW model bus type has been selected as the typical bus servicing the study area. The passenger capacity (seated) for this bus type is 40 (NABI "LFW Gen-III").

Based on these considerations, Table 3-16 provides the round-trip travel times for the new proposed routes for the Fairfield community.

Table 3-16. Roundtrip travel time for three new routes

TAZ	Route Length (miles)	Passengers per hour per direction	Number of Stops (Major and Minor)	Headway (hr)	Roundtrip Travel Time (min)	Trips Required (per hr)
444	11.18	387/(2*2)=97	26	0.33	85	97/40=2.425 (3)
664 666	10.88	280/(2*2)=70	34	0.5	85	70/40=1.75 (2)
Internal		496/(17)=30				
Internal (Clockwise)	9.3	15	37	1	35	15/40=1
Internal (Counter Clockwise)	9.3	15	37	1	35	15/40=1

3.3.6 Proposed Bus Schedule and Annual Bus Trips

As stated earlier, BJCTA provides bus service between downtown Birmingham's Central Station and the Fairfield area from 5 am to 10 pm on weekdays and from 6 am to 9 pm on Saturday.

There is no bus service for Sunday. This service will remain unaffected under the proposed transit improvement plan.

According to the proposed transit plan, Route 444 will serve the connection between Fairfield and TAZ 444 and Route 664 will cover the external work trips to TAZ 664 and 666. Four buses will be required for Route 444 and three for Route 664 to serve the work trips during work days (Monday through Friday, or 261 days/year). Service will start at 6 am from Fairfield toward the employment zones (and back), and from 4 pm to the employment zones from Fairfield (and back). Two of the buses on route 444 (bus nos. 1 and 2) will perform two round trips and the other two one round trip, whereas one of the buses on route 664 (bus no. 1) will perform two round trips and the other two one round trip during peak periods. Between their morning and afternoon shifts the buses will be available to provide on-demand service or return to the Central Station to assist other routes.

The internal route will operate from 5 am to 10 pm on a 30-minute schedule weekdays and Saturday (313 days a year). Two buses will be required to serve the internal trips scheduled every hour in opposite directions (clockwise and counterclockwise). Table 3-17 illustrates the proposed bus schedule for each route under the transit improvement plan. As the route lengths of the two external work routes (i.e. Route 444 and Route 664) are almost the same, the schedule is generalized for both of the routes.

Given these considerations, five buses will be dedicated to the new transit plan (two on Route 444, one on Route 664/666, and two serving the internal routes). The other four will provide service related to the proposed plan for less than 4 hours per day, and thus will be considered part time as far as calculation of operating expenses is concerned.

As mentioned earlier, BJCTA operates a fixed bus service (Route 41) to Fairfield. Considering Fairfield residents depend on this bus service for their travel to downtown Birmingham, the route is kept unchanged. Also, Route 45 services the connection between downtown Birmingham and Bessemer and passes from Fairfield. No changes are recommended for that existing route either. For that, the present transit use through Routes 41 and 45 are excluded from the analysis (except the use of present internal use of Route 41 for the bus frequency).

Thus on an annual basis the proposed transit plan will result in:

- Total Annual Additional Transit Trips by Users = (387+280) * (261) + (390) * (313) = 296,157 passenger trips per year,
- Annual Bus Trips = (Annual External Bus Trips) + (Annual Internal Bus Trips) = = (2) * (12) * (261) + (2) * (8) * (261) + (2) * (17) * (313) = 21,082 bus trips per year, and
- Annual Traveling Distance by Bus = (Internal Bus Services per Hour) * (Service Hours per Day) * (Internal Bus Service Days per Year) * (Internal Route Length) + (Number of Trips Required at One Peak Hour for Route 444) * (Number of Peak Hour Services) * (Number of Working Days) * (Route 444 Length) + (Number of Trips Required at One Peak Hour for Route 664) * (Number of Peak Hour Services) * (Number of Working

Days) * (Route 664 Length) = (2) * (17) * (313)* (9.3) + (12) * (2) * (261) * (11.18) + (8) * (2) * (261) * (10.88) = 214,437 miles per year.

Table 3-17. Bus schedule for external and internal routes

External Route 444								
Bus No.	**Morning Schedule (AM)**				**Evening Schedule (PM)**			
	Leaving Fairfield	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**	**Leaving Fairfield**	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**
1	6:00	6:41	6:44	7:25	4:00	4:41	4:44	5:25
2	6:20	7:01	7:04	7:45	4:20	5:01	5:04	5:45
3	6:40	7:21	7:24	8:05	4:40	5:21	5:24	6:05
4	7:00	7:41	7:44	8:25	5:00	5:41	5:44	6:25
1	7:30	8:11	8:14	8:55	5:30	6:11	6:14	6:55
2	7:50	8:31	8:34	9:15	5:50	6:31	6:34	7:15
External Route 664								
Bus No.	**Morning Schedule (AM)**				**Evening Schedule (PM)**			
	Leaving Fairfield	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**	**Leaving Fairfield**	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**
1	6:00	6:41	6:44	7:25	4:00	4:41	4:44	5:25
2	6:30	7:11	7:14	7:55	4:30	5:11	5:14	5:55
3	7:00	7:41	7:44	8:25	5:00	5:41	5:44	6:25
1	7:30	8:11	8:14	8:55	5:30	6:11	6:14	6:55
Internal Route								
Operates from 5 am to 10 pm on a 30-minute schedule								

Section 4
Case Study Analysis and Results

4.1 Introduction

This chapter focuses on the analysis of projected benefits and costs related to the implementation of the proposed transit improvement plan at Fairfield. This is used as a demonstration case study to guide future assessments of transit investment impacts as they relate to economic and health considerations. The results from such analyses can be used to determine if the TOD investment is justifiable from the economic point of view and help decision makers prioritize projects based on estimated returns for the investment.

4.2 Benefit-Cost Analysis Background

To perform a BCA, the benefits and costs associated with the proposed plan implementation must be considered. To find the benefit-cost (B/C) ratio, the total benefits (B) from implementing a project over a period of time (in monetized values) is then divided by the overall project costs (e.g. construction, operating, and maintenance costs), discounted at an appropriate rate to account for the time value of money (C). A B/C ratio greater than one implies that the benefits stemming from the project initiatives outweigh the costs, and the higher the B/C ratio, the better return for the investment is.

4.3 Estimation of Case Study Benefits

The benefits resulting from the proposed transit system and related improvements include user benefits, social benefits, and community benefits. These benefits are explored in greater detail next.

4.3.1 User Benefits

User benefits represent the monetary benefits induced by a project by changing the mobility of individual travelers. Reduced vehicle operating and ownership costs (including parking), reduced taxi fares, reduced likelihood of injury in a traffic accident etc. are potential user benefits related to increased transit use.

4.3.1.1 User Benefits Related to Vehicle Owning and Operating Cost Savings Single-occupancy vehicle riders (both “riders by choice” and “transit-dependent”) would incur vehicle-owning and -operating costs if they use their automobile instead of the transit system. Savings by transit are the savings per vehicle mile of avoided private automobile travel multiplied by the number of vehicle miles of avoided travel.

Table 4-1 shows a detailed breakdown of vehicle ownership and operating costs by type of vehicle and miles driven according to inputs from the American Automobile Association (2011). A combined cost for an average car ($1.36) has been selected in this analysis. According to a real-estate website (Zillow "Fairfield Demographics"), an average driver in Fairfield drives about 25.75 minutes. So the annual travel distance per automobile has been estimated to be 5,000 miles per year or 13.70 miles per day.

Table 4-1. Vehicle ownership and operating costs (in 2012 dollars)

	Small Sedan[1]	**Medium Sedan**[2]	**Large Sedan**[3]	**Average**[4]	**4WD Sport Utility Vehicle**[5]	**Minivan**[6]
Operating Costs (cents per mile)						
Gas	10.15	12.95	14.30	12.46	17.21	15.23
Maintenance	4.15	4.33	4.98	4.48	4.85	4.55
Tires	0.68	1.12	1.10	0.97	1.15	0.77
Total (cents per mile)	14.98	18.40	20.38	17.92	23.21	20.54
Annual Operating Costs	$749.42	$920.11	$1,019.09	$895.87	$1,160.49	$1,027.17
Annual Ownership Costs						
Full-coverage insurance	$960.51	$957.48	$1,016.06	$977.68	$921.12	$861.53
License, registration, taxes	$442.38	$582.77	$776.69	$600.95	$764.57	$624.18
Depreciation (15,000 miles annually)	$2,585.60	$3,569.34	$5,141.91	$3,765.28	$5,102.52	$4,149.08
Finance charge	$589.84	$803.96	$1,099.89	$831.23	$1,081.71	$867.59
Total	$4,578.33	$5,913.55	$8,034.55	$6,175.14	$7,869.92	$6,502.38
Decreased depreciation**	-$156.55	-$288.86	-$333.30	-$259.57	-$277.75	-$277.75
Total Cost per year	$5,171.20	$6,544.80	$8,720.34	$6,811.44	$8,752.66	$7,251.80
Total Cost per mile*	$1.03	$1.31	$1.74	$1.36	$1.75	$1.45

Notes: Cost per mile based on 5,000 miles per year
* Total cost per year ÷ Total miles per year
** Decreased depreciation for mileage under 15,000 miles annually averaged over five years
[1] 2010 Chevrolet Cobalt, Ford Focus, Honda Civic, Nissan Sentra, and Toyota Corolla
[2] 2010 Chevrolet Impala, Ford Fusion, Honda Accord, Nissan Altima, and Toyota Camry
[3] 2010 Buick Lucerne, Chrysler 300, Ford Taurus, Nissan Maxima, and Toyota Avalon
[4] Average for Small, Medium, and Large Sedan
[5] 2010 Chevrolet Traverse, Ford Explorer, Jeep Grand Cherokee, Nissan Pathfinder, and Toyota 4Runner
[6] 2010 Dodge Grand Caravan, Kia Sedona, Honda Odyssey, and Toyota Sienna

Source: AAA (2011)

The payment of the transit fare was considered as a partial offset. The BJCTA has a fare structure that includes single-ride tickets, 10-ride passes, 5-day and monthly passes, and discounts to qualified riders such as elderly/disabled, students, and children. According to BJCTA's *Audited Financial Statements* (2008), the total passenger fares collected in 2007 were $2,353,339 with an annual ridership in 2007 of 3,681,368 passengers (BJCTA "Metro area express"). Therefore, the average transit trip revenue was about $0.64 in 2007 dollars and $0.70 in 2012 dollars. Thus the net savings from the proposed transit plan were calculated as $5,310,688 per year as follows:

- User Cost Savings Related to Vehicle Owning and Operating
  = (Ownership and Operating Cost for Average Vehicle per Mile) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Automobile Trips per Year) – (Avg. Transit Trip Cost) * (Total Additional Transit Trips per Year)

  = ($1.36) * (13.70) * (296,157) – ($0.70) * (296,157) = $5,310,688 per year

4.3.1.2 User Benefits Related to Avoided Chauffeuring Costs The new transit system would displace about 296,157 automobile trips. Many of these trips are chauffeuring trips, where the driver provides rides to family, friends, and others. Goldsmith, *et al*. (2006) assumed half of these high-occupancy trips are chauffeured trips. Thus, about 148,079 chauffeuring trips, which involve a driver and a passenger, are expected to be displaced by the transit system. The total cost savings from the avoided chauffeured trips would be about $2,655,353 per year using same user savings for transit users replacing trips in single-occupancy cars:

- User Cost Savings Related to Avoided Chauffeuring
  = (Ownership and Operating Cost for Average Vehicle per Mile) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Chauffeuring Trips per Year) – (Avg. Transit Trip Cost) * (Total Additional Transit Trips per Year)

  = ($1.36) * (13.70) * (148,079) – ($0.70) * (148,079) = $2,655,353 per year

4.3.1.3 User Benefits Related to Traffic Accident Cost Savings The proposed new transit system will encourage people to use transit, which in turn would reduce automobile use, related traffic accidents on the roadway, and the costs associated with those accidents. Such costs include costs for medical treatment, emergency response, insurance, lost productivity, legal expenses, property damages, and the resulting transportation delays. Table 4-2 provides the definition of costs related to traffic accidents provided by Blincoe, *et al*. (2002).

Table 4-3 shows the cost per person and the cost per vehicle due to traffic crashes provided in Blincoe, *et al*. (2002), after being adjusted to 2012 dollars using the U.S. Consumer Price Index (CPI) (BLS). According to Blincoe, *et al*. (2002), injury cost components associate with related medical, emergency services, market productivity, household productivity, insurance administration, workplace costs, and legal/court costs. The remaining costs fall into the non-injury cost components of a traffic accident.

Using the information above and considering the number and type of traffic accidents in Fairfield as documented in Table 3-14, the total costs (health and economy related) resulting from the traffic accidents in Fairfield in 2010 are in Table 4-4.

Table 4-2. Definition of components of costs related to traffic accidents

Type of Cost	Definition
Medical Costs	The cost of all medical treatment including treatment during ambulance transport, emergency room and inpatient costs, follow-up visits, physical therapy, rehabilitation, prescriptions, prosthetic devices, and home modifications, associated with motor vehicle injuries including that given during ambulance transport.
Emergency Services	The cost associated with police and fire department response.
Vocational Rehabilitation	The cost of job or career retraining required as a result of road accident disability.
Market Productivity	The present discounted value (4 percent discount rate) of the lost wages and benefits over the victim's remaining life span.
Household Productivity	The present value of lost productive household activity due to hiring a person to accomplish the same tasks.
Insurance Administration	The administrative costs to process insurance claims and defense attorney costs.
Workplace Costs	The costs of workplace disruption, including the cost of retraining new employees, overtime required to accomplish work of the injured employee, and the administrative costs of processing personnel changes due to the loss or absence of an employee.
Legal Costs	The legal fees and court costs for civil litigation.
Travel Time	The monetary value of travel time delay for persons not involved in traffic crashes resulting traffic congestion from traffic accidents.
Property Damage	The value of vehicles, cargo, roadways, and other items damaged.

Source: Blincoe, *et al*. (2002)

Table 4-3. Cost per person and cost per vehicle due to traffic crashes (in 2012 dollars)

Type of Cost	Property Damage	Minor Injury	Major Injury	Fatal
	Cost per Vehicle	**Cost per Person**	**Cost per Person**	**Cost per Person**
Injury Components				
Medical	$0	$3,142	$173,541	$29,165
Emergency Services	$41	$128	$746	$1,100
Market Productivity	$0	$2,309	$211,733	$785,873
HH Productivity	$62	$755	$67,886	$252,834
Insurance Admin.	$153	$978	$41,690	$48,998
Workplace Cost	$67	$333	$6,306	$11,487
Legal Costs	$0	$198	$44,329	$134,822
Subtotal	$323	$7,843	$546,231	$1,264,279
Non-Injury Components				
Travel Delay	$1,060	$1,026	$3,938	$12,075
Prop Damage	$1,959	$5,074	$9,911	$13,560
Subtotal	$3,019	$6,100	$13,849	$25,635
Total	$3,342	$13,943	$560,080	$1,289,914

Source: Blincoe, *et al*. (2002)

Table 4-4. Total costs due to traffic crashes in Fairfield in 2010 (in 2012 dollars)

Type of Cost	Type of Collision				
	Property Damage	**Minor Injury**	**Major Injury**	**Fatal**	**All Types**
Injury Components					
Medical	$0	$175,952	$3,123,738	$58,330	$3,358,020
Emergency Services	$17,712	$7,168	$13,428	$2,200	$40,508
Market Productivity	$0	$129,304	$3,811,194	$1,571,746	$5,512,244
HH Productivity	$26,784	$42,280	$1,221,948	$505,668	$1,796,680
Insurance Admin.	$66,096	$54,768	$750,420	$97,996	$969,280
Workplace Cost	$28,944	$18,648	$113,508	$22,974	$184,074
Legal Costs	$0	$11,088	$797,922	$269,644	$1,078,654
Subtotal	$139,536	$439,208	$9,832,158	$2,528,558	$12,939,460
Non-Injury Components					
Travel Delay	$457,920	$57,456	$70,884	$24,150	$610,410
Prop Damage	$846,288	$284,144	$178,398	$27,120	$1,335,950
Subtotal	$1,304,208	$341,600	$249,282	$51,270	$1,946,360
Total	$1,443,744	$780,808	$10,081,440	$2,579,828	$14,885,820

From the Origin-Destination trip table (total of 999 TAZs) provided by the Regional Planning Commission of Greater Birmingham, there are 71,144 automobile trips in and out of Fairfield per day. The transit system will replace 1,057 (667 external + 390 internal) trips per day, which is 1.49% of the total trips. Goldsmith, *et al*. (2006) estimated that about a third of the associated savings accrue to the users. So the user cost savings due to reduced number of accidents associated with reduced automobile trips will be $73,933 ($64,266 and $9,667 health and economy related respectively) per year. In addition, health-related and economy-related user cost savings will be realized from the 10% shift to transit as follows:

- Health related User Cost Savings
  = (Total Health Cost related to Traffic Accidents) * (User Share) * (% of Overall Trips)
  $= (\$12{,}939{,}460) * (\frac{1}{3}) * (1.49\%) = \$64{,}266$ per year
- Economy related User Cost Savings
  = (Total Economic Cost related to Traffic Accidents) * (User Share) * (% of Overall Trips)
  $= (\$1{,}946{,}360) * (\frac{1}{3}) * (1.49\%) = \$9{,}667$ per year

4.3.1.4 User Benefits Related to Pain and Suffering Cost Savings In addition to direct economic costs, traffic crashes also induce pain and suffering costs for the victims. Table 4-5 shows valuation of the pain and suffering and loss of life due to traffic accident injuries and fatalities based on “quality-of-life years” lost. The loss of quality-of-life years is based on the duration and severity of health problems due to accidents, where cost is associated with the willingness to pay to avoid pain, suffering, and loss of life due to an accident. The estimates in Table 4-7 are based on the National Highway Traffic Safety Administration recommendations as cited in Blincoe, *et al*. (2002) after being adjusted to 2012 dollars using the CPI.

Table 4-5. Cost of loss of quality of life due to traffic accidents (in 2012 dollars)

	Minor Injury	Major Injury	Fatal
Persons Involved	56	18	2
Costs per Person	$5,881	$630,144	$3,153,716
Subtotal Cost	$329,336	$11,342,592	$6,307,432
Total Cost	$17,979,360		

Sources: Collision data from CAPS (2011) and cost per person and cost per vehicle from Blincoe, *et al*. (2002)

Using the 2010 Fairfield community crash data, the total cost of loss of quality of life due to accident injures is found to be $11,671,928 ($329,336 for minor and $11,342,592 for major injury) per year and the cost of loss of life is $6,307,432 per year for a total of $17,979,360 per year. The reduction of automobile trips due to the 10% shift to transit is expected to lead to 1.49% reduction in overall trips and associated crashes, further resulting in $267,893 pain and suffering cost savings per year as shown below:

- Health related User Cost Savings related to Loss of Quality of Life
  = (Total Cost of Loss of Quality of Life) * (% of Overall Trips)
  = ($17,979,360) * (1.49%) = $267,893 per year

4.3.1.5 User Benefits Related to Parking Cost Savings The proposed transit plan is expected to result in reduced needs for infrastructure devoted to parking and the costs associated with it. Such costs include land costs, construction, operations, and maintenance costs.

Land costs include the cost of buying, leasing, or renting the parking land and the opportunity cost of public and private land. Construction costs include designing and planning, materials, and labor. Maintenance and operations costs include street sweeping, snow removal, security, electricity, salaries for cashiers, insurance, structural maintenance, and management of the facilities.

Table 4-6 shows recommended values for calculating parking cost savings as a result of shifting trips from automobile to public transit, depending on the destination and trip type, provided in (Litman 2012). These savings are based on Park & Ride trip savings considering the differences in parking costs between Park & Ride and worksite parking facilities.

Table 4-6. Typical parking costs per round trip (in 2012 dollars[1])

Type of Trips	Small City	Medium City	Large City
Commute Trips	$3.00	$6.00	$9.00
Other Trips	$2.00	$4.00	$6.00
Average	$2.50	$5.00	$7.50

[1] Currency year is assumed to be the same as the publication year.
Source: Litman (2012)

As far as the case study is concerned, the proposed transit improvement plan will replace 387 (194 round trips) automobile trips to TAZ 444 and 280 (140 round trips) automobile trips to TAZ 664 and 666 for work-related purposes, as well as 390 (195 round trips) internal automobile trips. Thus a total of $370,523 can be saved per year due to reduced parking infrastructure and use costs at the work and attraction places. According to EPBQD (2002), users share between 10% and 50% of total parking costs whereas Litman (2012) estimated between 29% and 56% are borne directly by users. Goldsmith, *et al*. (2006) estimated that users share 25% of the costs associated with parking and the rest accrues to the community at large. This estimate is adopted in the case study for estimation of user cost savings as follows:

- Total Cost Savings related to Parking
  = (Avg. Parking Cost Value per Round Trip) * (Total Displaced Daily External Round Trips for Work) * (Total Working Days) + (Avg. Parking Cost Value per Round Trip) * (Daily Internal Round Trips) * (Internal Bus Service Days per Year)
  = ($2.5) * (194+140) * (261) + ($2.5) * (195) * (313) = $370,523 per year
- User Cost Savings related to Parking
  = (Total Cost Savings Related to Parking) * (User Share for Parking)
  = ($370,523) * (25%) = $92,631 per year.

4.3.2 Social and Community Benefits

The availability of transit service increases accessibility to jobs, medical services, social services, educational opportunities, recreation, and other events for those who are transit-dependent due to age, disability, or lack of automobile ownership. Furthermore, an increase in transit use benefits the community by reducing parking and other transportation-related services, congestion and traffic accidents related expenses, and pollution related costs mostly in the form of lower taxes. A review of such benefits and calculation of associated savings from the implementation of the new transit improvement plan in Fairfield follows.

4.3.2.1 Social Benefits Related to Use of Transit Transit use makes different types of services affordable for transit-dependent populations. Table 4-7 identifies the potential beneficiaries as summarized by Goldsmith, *et al*. (2006).

For the study community, assuming that the full price bus fare is kept at $1.50 for a single ride and the average travel distance of transit is 10.25 miles, the average bus fare paid by users of the bus amounts to about $0.15 per passenger mile. Given that taxi use in Fairfield is almost negligible, automobiles would be the next best alternative to transit. The average automobile use cost per passenger mile is $1.36 per mile (from Table 4-1) (AAA 2011). Thus the cost over and above the bus ride cost would be $1.21 per mile. The literature recommends applying the “50% rule,” which reduces the average automobile cost per passenger above that of transit to half, or $0.605 per mile. The 50% rule implies that the value of a trip for the average access user is about half the difference between the bus and next best alternative’s cost—here the automobile cost. Assuming some riders would share a ride with others (1.5 passengers per vehicle), the total value of these trips to the riders above their cost is $119,450 per year, as calculated below.

Table 4-7. Types of access enabled by transit

Type of Access	Beneficiaries
Work	Workers benefit from increased income and improved quality of life from access to the jobs, including employers benefit due to access to a larger labor pool, decreased turnover, reduced absenteeism, and reduced parking costs and economic benefit as a result of more working people and fewer people collecting public support payments.
Social Services	Cost savings due to use of transit by clients of social service agencies who rely on the bus to get to agencies to apply for benefits, to receive services, or to collect food or aid.
Medical Services	Residents and visitors benefit due to better access to medical care, which in turn can improve quality of life and reduce long-term medical costs, and community benefits from improved public health and reduced costs of medical care.
Education	Student benefits from better access to schools and universities, economic benefits from having more educated residents with skills to perform higher valued work in the economy, and family benefits from broader choices in which schools children can attend.
Shopping	Accessibility to shopping by residents, tourists, and visitors that improves the quality of life or the quality of the visit to the community by broadening the range of shopping choices and economic benefits resulting from their spending in the local economy.
Tourism Destinations	Visit to destinations by tourists and instate visitors.

Source: Goldsmith, *et al*. (2006)

- Social Cost Savings
  = (Extra Cost for using Automobile rather than Bus) * (Total Displaced Automobile Trips per Year) / (Assumed Ridership per Automobile)
  = ($0.605) * (296,157) / (1.5) = $119,450 per year

4.3.2.2 Community Benefits Related to Traffic Services Savings Traffic services include traffic signals, street lightings, street maintenance, parking, ambulance services, and police services. An increase in transit use, coupled with a reduction in automobile use, would reduce the cost for traffic services at the community level. Table 4-8 provides estimates of traffic service costs per vehicle mile traveled (VMT) by the sources cited in the literature after being adjusted to 2012 dollars. These sources suggest that the traffic service cost per vehicle mile is equal for buses and automobiles.

In this case study the costs proposed from Delucchi (1997), quoted in EPBQD (2002), have been adopted for estimating the total savings in traffic services.

Based on the assumptions of the case study and considering the values proposed by Delucchi (1997) for low estimates, the community benefits related to traffic service savings under the proposed transit improvement plan for Fairfield are found to be $51,495 per year as shown below.

- Community Cost Savings Related to Traffic Services
  = (Traffic Services Costs per VMT for Automobiles) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Automobile Trips per Year) – (Traffic Services Costs per VMT for Buses) * (Total Transit Travel Distance per Year)

= ($0.0134) * (13.70) * (296,157) – ($0.0134) * (214,437) = $51,495 per year

Parking and traffic accident savings were not included in the calculation and were calculated separately.

Table 4-8. Traffic service costs per vehicle mile traveled (in 2012 dollars)

Source	Automobiles	Bus
Litman (2009)		
Rural	0.0077	0.0077
Urban		
Peak	0.0220	0.0220
Off-Peak	0.0143	0.0143
Average	0.0132	0.0132
Delucchi (1997)		
Low	$0.0134	$0.0134
High	$0.0217	$0.0217
Moore and Thorsnes (1994)		
Low	$0.0154	$0.0154
High	$0.0616	$0.0616

Sources: Delucchi (1997) and Moore and Thorsnes (1994) cited in EPBQD (2002)

4.3.2.3 Community Benefits Related to Traffic Congestion Congestion occurs when traffic demand exceeds roadway capacity. It is especially common during the peak hours of the day. Due to its higher occupancy rate, transit relieves the pressure on roadways, reduces automobile trips, and decreases congestion. This often results in measurable community benefits.

Table 4-9 provides a summary of estimations of the cost of congestion per VMT based on national studies. Both Litman (2009) and FHWA (1997) suggest that congestion costs for buses are almost double of those of automobiles.

For the case study, the reduction in congestion made by replacing automobile trips by bus transit trips is considered using low estimates of congestion costs per VMT for cars and buses for urban highways proposed by FHWA. Overall such costs were estimated as follows:

- Community Cost Savings from Traffic Congestion Reduction
  = (Traffic Congestion Costs per VMT for Automobiles) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Automobile Trips per Year) – (Traffic Services Costs per VMT for Buses) * (Total Transit Travel Distance per Year)

  = ($0.0216) * (13.70) * (296,157) – ($0.0446) * (214,437) = $78,075 per year

Table 4-9. Traffic congestion costs per vehicle mile traveled (in 2012 dollars)

Source	Average Car	Bus
Litman		
Rural Highways	$0.00	$0.00
Urban Highways		
Peak	$0.143	$0.297
Off Peak	$0.022	$0.044
Average	$0.0385	$0.0759
Federal Highway Administration		
Rural Highways		
Low	$0.0045	$0.0083
Medium	$0.0169	$0.0313
High	$0.0496	$0.0919
Urban Highways		
Low	$0.0216	$0.0446
Medium	$0.0820	$0.1687
High	$0.2412	$0.4962
All Highways		
Low	$0.0157	$0.0294
Medium	$0.0591	$0.1113
High	$0.1738	$0.3272

Sources: Litman (2009) and FHWA (1997)

4.3.2.4 Community Benefits Related to Parking The total annual savings from reduced demand for parking was found to be $370,523. Goldsmith, *et al*. (2006) estimated that the community pays about 75% of the total parking costs. The community savings for businesses and taxpayers, due to reduction in parking facility demand as a result of fewer cars, include savings from reduced land purchase, facility construction cost, and operations and maintenance costs of parking facilities and parking areas on roadways, for a total of $277,893 a year.

- Community Cost Savings related to Parking
  = (Total Cost Savings Related to Parking) * (Community Share)
  = ($370,523) * (75%) = $277,893 per year

4.3.2.5 Community Benefits Related to Traffic Accidents As stated, a shift from automobile to transit reduces the traffic accidents and the costs associated with them. For the case study, the total annual health and economic cost due to traffic accidents was found to be $12,939,460 and $1,946,360 per year respectively. Goldsmith, *et al*. (2006) estimated that about two thirds of these savings accrue to the community at large (for businesses and taxpayers) as reduced medical costs, emergency services, insurance payments, lost value of productive work, delays in traffic, and property damage. Thus, the total community savings due to reduced traffic accidents resulting from the adoption of the proposed transit improvement plan was calculated to be $147,866 ($128,532 health related and $19,334 economy related) per year for the city of Fairfield.

- Health-related Community Cost Savings from Reduced Traffic Accidents
  = (Total Health Cost related to Traffic Accidents) * (Community Share) * (% of Overall Trips)
  = ($12,939,460) * ($\frac{2}{3}$) * (1.49%) = $128,532 per year
- Economy-related Community Cost Savings from Reduced Traffic Accidents

= (Total Economic Cost related to Traffic Accidents) * (Community Share) * (% of Overall Trips)

= ($1,946,360) * ($\frac{2}{3}$) * (1.49%) = $19,334 per year

4.3.2.6 Community Benefits Related to Air Pollution Air pollution costs refer to air-pollution damages caused by motor-vehicle emissions, including human health, environmental damage, crop damage, and esthetic degradation. Table 4-10 summarizes the impacts of various motor vehicle (including transit) pollution emissions based on the literature, and Table 4-11 presents the health-related effects of various air pollutants. Table 4-12 summarizes the health, visibility, and forest and vegetable cost of emissions from motor vehicles adjusted to 2012 dollars, and Table 4-13 provides the total cost related to the air pollution per VMT for motor vehicles.

Table 4-10. Impacts of motor vehicle pollutants

Emission	Description	Sources	Harmful Effects	Scale
Carbon dioxide (CO_2)	A by-product of combustion	Fuel production and engines	Climate change	Global
Carbon monoxide (CO)	A toxic gas which undermines blood's ability to carry oxygen	Engine	Human health, climate change	Very local
Chlorofluorocarbon (CFCs)	Durable chemical harmful to the ozone layer and climate	Older air conditioners	Ozone depletion	Global
Fine Particulates (Particulate Matter - PM_{10}; $PM_{2.5}$)	Inhalable particles consisting of bits of fuel and carbon	Diesel engines and other sources	Human health, aesthetics	Regional
Hydrocarbons (HC)	Unburned fuel forms ozone.	Fuel production and engines	Human health, ozone precursor	Regional
Lead	Element used in older fuel additives	Fuel additive and batteries	Circulatory, reproductive, and nervous system	Local
Methane (CH_4)	Significant "greenhouse" gas	Fuel production and engines	Climate Change	Global
Nitrogen oxides (NO_x)	Various compounds some are toxic, all contribute to ozone	Engine	Human health, ozone precursor, ecological damages	Local and regional
Ozone (O_3)	Major urban air pollution problem resulting from NO_x and VOCs combined in sunlight	NO_x and VOC	Human health, plants, aesthetics	Regional
Road dust	Dust created by vehicle movement.	Vehicle use	Human health, aesthetics	Local
Sulfur oxides (SO_x)	Lung irritant and causes acid rain.	Diesel engines	Human health risks, acid rain	Local and regional
Volatile organic hydrocarbons (VOCs)	Organic compounds that form aerosols	Fuel production and engines	Human health and ozone precursor	Local and regional
Toxics (e.g. benzene)	VOCs that are toxic and carcinogenic.	Fuel production and engines	Human health risks	Very local

Source: Litman (2009)

Table 4-11. Human health effects of common pollutants

Pollutant	Quantified	Not yet Quantified	Other Possible Effects
Ozone	Mortality, respiratory symptoms, minor RADs, respiratory RADs, hospital admissions, asthma attacks, changes in pulmonary function, chronic sinusitis and hay fever	Increased airway, responsiveness to stimuli, Centroacinar fibrosis, Inflammation in the lung	Immunologic changes, chronic respiratory diseases, extrapulmonary effects (changes in function or structure of organs)
Particulate matter/ TSP/ Sulfates	Mortality, chronic and acute bronchitis, hospital admissions, lower respiratory illness, upper respiratory illness, chest illness, respiratory symptoms, minor RADs, all RADs, days of work loss, moderate or worse asthma status for asthmatics	Changes in pulmonary function	Inflammation of the lung, chronic respiratory diseases other than chronic bronchitis
Carbon Monoxide	Hospital admissions– congestive heart failure, decreased time to onset of angina	Behavioral effects, Other hospital admissions	Other cardiovascular effects, Developmental effects
Nitrogen Oxides	Respiratory illness	Increased airway responsiveness	Inflammation of the lung, immunological changes, decreased pulmonary function
Sulfur Dioxide	Morbidity in exercising, asthmatics, changes in pulmonary function, respiratory symptoms		Respiratory symptoms in non-asthmatics
Lead	Mortality, hypertension, nonfatal coronary heart disease, nonfatal strokes, intelligence quotient (IQ) loss effect on lifetime earnings, IQ loss effects on special education needs	Health effects for other age ranges other than those studied, neurobehavioral function, other cardiovascular diseases, reproductive effects, fetal effects from maternal exposure, delinquent and antisocial behavior in children	

Source: Litman (2009)

Table 4-12. Health, visibility, and forest and vegetable costs of emissions from motor vehicles (in 2012 dollars)

	Severity	PM_{10}	VOCs	CO	NO_x	SO_x	VOCs and NO_x
	Grams per Vehicle Mile Traveled						
	Low	0.2	3.1	38.2	3.6	0.2	6.7
	High	0.3	3.7	45.3	4.0	0.2	7.7
	Dollar Costs of Damages per Kg Emitted						
Health	Low	16.2825	0.1670	0.0167	1.9539	11.5230	0.0167
	High	223.4126	1.9205	0.1503	28.8743	108.9174	0.1837
Visibility	Low	0.6680	0.0000	0.0000	0.3340	1.5030	0.0000
	High	6.5130	0.1670	0.0000	1.8370	6.6800	0.0000
Forest and Vegetation	Low	0.0000	0.0000	0.0000	0.0000	0.0000	0.3173
	High	0.0000	0.0000	0.0000	0.0000	0.0000	0.5010
Total	Low	16.9505	0.1670	0.0167	2.2879	13.0260	0.3340
	High	229.9256	2.0875	0.1503	30.7113	115.5974	0.6847

Source: McCubbin and Delucchi (1996)

Table 4-13. Air pollution costs of motor vehicles per vehicle mile traveled (in 2012 dollars)

	Severity	PM_{10}	VOCs	CO	NO_x	SO_x	VOCs and NO_x	All Pollutants
Health	Low	$0.0033	$0.0005	$0.0006	$0.0070	$0.0023	$0.0001	$0.0139
	High	$0.0670	$0.0071	$0.0068	$0.1155	$0.0218	$0.0014	$0.2196
Visibility	Low	$0.0001	$0.0000	$0.0000	$0.0012	$0.0003	$0.0000	$0.0016
	High	$0.0020	$0.0006	$0.0000	$0.0073	$0.0013	$0.0000	$0.0113
Forest and Vegetation	Low	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0021	$0.0021
	High	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0039	$0.0039
Total	Low	$0.0034	$0.0005	$0.0006	$0.0082	$0.0026	$0.0022	$0.0176
	High	$0.0690	$0.0077	$0.0068	$0.1228	$0.0231	$0.0053	$0.2347

Table 4-14 compares the annual emissions from old diesel, new diesel, and new CNG transit buses based on the work of Lowell (2012), which focuses on analyzing the tailpipe emissions. Pollution emissions, except CO of CNG buses, are significantly lower than those for a diesel bus.

Table 4-15 shows the air-pollution costs of CNG buses per VMT using the dollar costs of damages per kg of emissions, from McCubbin and Delucchi (1996). In this study, air-pollution costs are estimated using the low estimate from the TCRP study.

Table 4-14. Annual emissions from diesel and CNG buses

Transit Vehicle Type	Pollutant (g/mi)			
	NO_x	PM	CO	VOC
2012 Diesel	0.90	0.015	0.74	0.14
2012 CNG	3.00	0.003	10.02	0.00
2000 Diesel	14.67	0.779	8.33	1.31

Source: Lowell (2012)

Table 4-15. Air pollution costs of CNG buses per vehicle mile traveled (in 2012 dollars)

	Severity	PM_{10}	VOCs	CO	NO_x	All Pollutants
Health	Low	$0.0000	$0.0000	$0.0002	$0.0059	$0.0061
Visibility		$0.0000	$0.0000	$0.0000	$0.0010	$0.0010
Forest and Vegetation		$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
Total		$0.0000	$0.0000	$0.0002	$0.0069	$0.0071

Of the $0.0176 air pollution cost per VMT for automobiles, $0.0139 is health related and the rest is economic related. For CNG buses, $0.0061 is health related and the rest is economic related.

Based on the case study and the assumptions and inputs from the literature, the following shows how adopting the proposed transit plan would reduce costs.

- Health-related Community Cost Savings from Reduced Air Pollution

= (Health-related Air Pollution Cost per VMT for Automobiles) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Automobile Trips per Year) – (Health related Air Pollution Cost per VMT for CNG Buses) * (Total Transit Travel Distance per Year)
= ($0.0139) * (13.70) * (296,157) – ($0.0061) * (214,437) = $55,090 per year

- Economy-related Community Cost Savings from Reduced Air Pollution
= (Economy-related Air Pollution Cost per VMT for Automobiles) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Automobile Trips per Year) – (Economy related Air Pollution Cost per VMT for CNG Buses) * (Total Transit Travel Distance per Year)
= ($0.0037) * (13.70) * (296,157) – ($0.0010) * (214,437) = $14,798 per year

4.3.2.7 Option Value Community residents may use transit as an alternate transportation option during an emergency or rare events. Transit is a valuable resource, for instance, during bad weather or when roadway conditions make driving hazardous, such as the presence of disabled vehicles, special events where parking is limited, or temporarily disabled of drivers. Litman (2012) approximated the option value of a community to be 1 to 10 times of the total population within the community. Using the lower value of approximation to stay on the conservative side, the option value was found to be $11,117 per year for Fairfield.

- Community Benefits = (Option Value) * (Total Population) = ($1) * (11,117) = $11,117 per year

4.3.2.8 Public Health

4.3.2.8.1 Direct Health Benefits The health savings resulting from reduced traffic accidents and related pain and suffering and the savings from reduced air pollution were calculated earlier. Other public-health savings could result from reduced stress and increased physical activity. Public transportation provides an opportunity for bus passengers to relax, read, or otherwise enjoy their trips rather than driving, which is often linked to stress and pressure.

According to the Center for Transportation Excellence (2012), “The stress of driving in congested conditions is linked directly to a long list of health problems, including cardiovascular disease, suppressed immune system functioning, and strokes, as well as more headaches, colds, and flu symptoms. Studies indicate that less travel time, more predictability, enhanced control, and less effort required to make a trip reduces the stress levels and negative health effects associated with driving.”

As far as inactivity is concerned, various tools mentioned in the literature may estimate the cost of physical inactivity associated with automobile use. For the Fairfield case study, the estimates of losses in worker productivity, increases in medical care costs, and increases in workers’ compensation due to physical inactivity are obtained from the methodology proposed by Chenoweth and Bortz (2010). The major component of the costs of physical inactivity are “productivity losses,” as employees get sick and either do not report to work or work below their capabilities.

4.3.2.8.1.1 Medical Care Seven medical conditions (MDC) associated with physical inactivity are identified based on the research reported in Chenoweth and Bortz (2010), including cancer; injuries and poisoning; and endocrine, metabolic, circulatory, musculoskeletal, mental, and nervous-system conditions. As shown in Table 4-16, Chenoweth and Bortz (2010) used medical-care costs obtained from health insurers (private and public) in seven states to calculate per claimant and per capita claim and cost norms. Medical-care costs reflected inpatient and outpatient claims payments associated with employer-paid health plans and out-of-pocket expenses incurred by patients. It should be noted that pharmaceutical (prescription) and over-the-counter (OTC) costs were not included in medical care. A total medical-care cost of physical inactivity for the mentioned MDC reported in the literature was $50.44 per person in 2004.

Using the literature inputs and study assumptions, the costs related to medical care were calculated for the case study. The medical-cost savings from the shift of 529 Fairfield automobile users (see Table 3-13) to transit according to the proposed transit plan are estimated as $32,287 (in 2012 dollars) per year. It is:

- Medical Cost Savings
  = (Medical Care Cost of Physical Inactivity per Person) * (Additional Transit Users) * (Inflation Adjustment Factor)
  = ($50.44) * (529) * (1.21) = $32,287 per year

Table 4-16. Worksheet for medical costs computation (in 2004 dollars)

	Section I Major Diagnostic Categories							All MDC
Cost Unit Variable	**Breast and Colon Cancer**	**Circulatory**	**Diabetes**	**Hip Fracture**	**Anxiety & Depression**	**Musculo-skeletal**	**Carpal Tunnel Syndrome**	**Total**
7-state $ distribution	0.097	0.166	0.036	0.001	0.064	0.211	0.005	0.58
MDC%: Targeted MDCs	0.167	0.286	0.062	0.002	0.110	0.364	0.009	1.00
Ave. Cost per MDC	3356	1,688	1,176	24,050	1,040	812	1,878	
# of claims per capita	0.013	0.043	0.043	0.002	0.108	0.131	0.010	0.35
Annual cost per capita	44.11	72.83	50.72	54.32	112.57	106.18	18.46	
Phys inact. R.F. weight	0.13	0.16	0.22	0.08	0.07	0.065	0.15	
Risk factor cost	5.73	11.65	11.16	4.35	7.88	6.90	2.77	50.44
	Section II Cost Per Claimant							**State Avg.**
N. Carolina	1,533	2,683	759	31,374	1,529	1,754	621	5,750.43
New York	2,699	2,179	1,899	16,335	561	406	2,205	3,754.86
California	4,075	364	597	16,350	918	265	230	3,257.00
Texas	11,073	2,349	1,718	32,235	1,685	863	2,750	7,524.71
Michigan	1,669	961	2,295	23,395	1,400	1,085	4,990	5,113.57
Massachusetts	1,510	1,784	821	24,867	365	1,082	365	4,399.14
Washington	932	1,497	140	23796	819	231	1,988	4,200.43
H. Average	3,356	1,688	1,176	24,050	1,040	812	1,878	

	Section III Per Capita Claims							State Avg.
N. Carolina	0.017	0.088	0.093	0.0058	0.028	0.054	0.016	0.043114
New York	0.008	0.172	0.023	0.00034	0.181	0.195	0.0002	0.082791
California	0.008	0.17	0.023	0.00174	0.182	0.195	0.009	0.084106
Texas	0.004	0.127	0.067	0.0003	0.003	0.202	0.005	0.058329
Michigan	0.023	0.028	0.007	0.00591	0.002	0.027	0.017	0.015701
Massachusetts	0.024	0.023	0.024	0.00035	0.176	0.224	0.02	0.070193
Washington	0.008	0.055	0.065	0.00137	0.186	0.018	0.0016	0.047853
I. Avg of 7 states	0.013	0.095	0.043	0.002	0.108	0.131	0.010	0.057441

Population Profile	**# Adults**
N. Carolina	6,085,266
New York	13,922,216
California	24,500,000
Texas	15,015,000
Michigan	7,567,350
Massachusetts	4,850,710
Washington	4,519,892
Total (7 states)	76,460,434
Average of 7 states	10,922,919
USA adults	202,000,000
7 states as % of USA	0.38

Source: Chenoweth and Bortz (2010)

4.3.2.8.1.2 Workers' Compensation Table 4-17 provides an estimation of the costs associated with workers' compensation using data from seven states (Chenoweth and Bortz 2010). Based on this reference, the total national cost of worker compensation for physical inactivity for the musculoskeletal strains and sprains was $8.82 per person in 2004.

Using this number as a reference, the health savings from transit use according to the proposed plan in the Fairfield case study are calculated as $5,646 (2012 dollar value) per year. It is:

- Workers' Compensation Cost Savings
  = (Workers' Compensation of National Cost of Physical Inactivity per Person) * (Additional Transit Users) * (Inflation Adjustment Factor)
  = ($8.82) * (529) * (1.21) = $5,646 per year

4.3.2.8.1.3 Lost Productivity Table 4-18 shows the cost of lost productivity per worker by two measures: (a) absenteeism and (b) presenteeism. The available literature (Chenoweth and Bortz 2010) considers an annual work schedule consisting of 2,000 hours (based on 50 weeks at 40 hours per week) and determines losses due to absenteeism and presenteeism from worksite studies. Median compensation costs were obtained from state labor or commerce departments. Chenoweth and Bortz (2010) estimates that the total cost of physical inactivity due to lost productivity in the targeted population at the two studied worksites as $1,466.36 per person. The lost productivity cost savings from transit use according to the proposed plan in the Fairfield case study are calculated as $938,063 (2012 dollars) per year:

- Lost Productivity Cost Savings
  = (Lost Productivity Cost per Person) * (Additional Transit Users) * (Inflation Adjustment Factor)
  = ($1,466.36) * (529) * (1.21) = $938,063 per year

Table 4-17. Cost calculation of workers' compensation (in 2004 dollars)

State	# of Adults	# of Workers	Claims per Worker	Total # W.C. Claims	# of Strain/ Sprains	Total $ Paid Strain/Sprain	Avg $ Per Str/Spr Claim	Per Worker $
California	24,500,000	14,300,483	0.018	257,409	18,408	2,632,801,863	22,235	184.11
North Carolina	6,085,266	3,914,300	0.018	70,457	32,410	663,473,380	20,471	169.50
New York	13,922,216	8,850,100	0.018	159,302	73,279	1,401,311,028	19,123	158.34
Massa-chusetts	4,850,710	2,971,072	0.018	53,479	24,600	311,392,827	12,658	104.81
Michigan	7,567,350	5,136,130	0.018	92,450	42,527	813,246,812	19,123	158.34
Texas	15,015,000	9,351,500	0.018	168,327	77,430	1,635,795,053	21,126	174.92
Washington	6,083,301	3,360,000	0.018	60,480	27,821	290,236,998	19,123	86.38
7 State Avg.	13,003,974	7,980,598	0.018	143,651	66,079	1,291,376,327	22,310	135.72
Source:	Census Bureau Census Bureau OSHA/ODG[1]				OSHA/ODG[1] or state database[2]		WCRI[3]	
Str/Sprain Per Worker Cost				%of Str/Sprain Due to Physical Inactivity			Physical Activity Per Worker National Cost	
$135.72				0.065			$8.82	

Footnotes:
[1] OHSA data published *in Official Disability Guidelines*, 6th Edition, 2001.
[2] Strains and strains obtained from actual state-wide databases 10a-10b
[3] Workers' Compensation Research Results Institute (Benchmarks for eleven states) data listed at www.wcrinet.org [Benchmark states included California, Massachusetts, North Carolina, and Texas; New York, Michigan, and Washington data are estimates based on an average of the other four states]
[4] Based on a review of the professional literature: 11b-22b. Note: Physical inactivity is assigned a risk factor weight of 6.5% (.065), based on the methodology listed in section 1.F.1.

Source: Chenoweth and Bortz (2010)

4.3.3.8.1.4 Total Direct Health Benefits The total direct public-health cost savings from additional physical activity for the case study's transit development plan are summarized in Table 4-19. The total direct public-health benefits from the proposed plan total $975,996 per year.

4.3.2.8.2 Indirect Health Benefits Inefficiencies due to replacement workers, lost opportunities, and other eventual costs (e.g. longer rehabilitation times, drug reactions, and additional usage of medical services) are responsible for the indirect costs for medical care. According to the literature, the ratio of indirect costs to direct costs for various medical conditions ranges from 1.2:1 (low) to 15:1 (high). A conservative ratio of 3:1 is applied for indirect medical-care costs in this case study, while a ratio of 4:1 is used to reflect indirect-to-direct cost ratios for worker compensation (CANBNC 2005; Chenoweth, *et al*. 2003).

The multiplier for indirect costs for workers' compensation is generally higher than that of medical care expenses. This is because of the odds that would delay or impair an individual's return-to-work timeframe and on-the-job performance (e.g. adjudication, poor attitude, liberal return to work, etc.) (CANBNC 2005). Lost productivity is generally classified as a direct cost; therefore, indirect costs are not applicable in lost productivity cost category. All the values are adjusted to 2012 dollars (see Table 4-20).

Table 4-18. Worksheet of lost productivity costs (in 2004 dollars)

Cost Unit	Average Hours Lost per Year[1]	Scheduled Workload[2]	Lost Hours as % of Workload[3]	Median Compensation[4]	# Workers	Lost Productivity Costs
Absenteeism	18.08	2,000	0.00904	$36,929	2,000	$667,676.32
Presenteeism	140.75	2,000	0.070375	$36,929	2,000	$5,197,756.75
					Subtotal	$5,865,433.07
				x% Phy. Inactive		0.5
				Total Lost Prod Cost		$2,932,716.535
				Per Capita Cost		**$1,466.36**

Footnotes:
[1]Based on earlier research studies

Source	# of Hours	Days Per Year
Edington	3.5	0.43
Burton & Conti	16	2
IHRSA	7.6	0.95
Lechner, *et al*.	38.4	4.8
Opatz	24.88	3.11
Average	18.08	2.26

[1] Presenteeism hours based on the average of 131.5 [2] Based on 50 weeks of 40 hours per week
[3] Average hours lost per year ("B") divided by scheduled workload ("C")
[4] Annual salary and benefits
Source: Chenoweth and Bortz (2010)

Table 4-19. Total direct health cost savings per year (in 2012 dollars)

Cost Unit	Description	Cost Savings
Medical Care Workers	Average medical care cost of physical inactivity	$32,287
Compensation Lost	Average cost per worker due to physical inactivity	$5,646
Productivity	Average cost due to workload lost to physical inactivity	$938,063
Total		$975,996

Table 4-20. Total indirect public health cost savings per year (in 2012 dollars)

Cost Unit	Description	Multiplier (per capita per year) (2004)	Transit Users	CPI Multiplier and Applied Ratio Factor	Cost Savings
Medical Care	Average medical care cost of physical inactivity	$50.44	529	(1.21) * (3)	$96,859
Workers' Compensation	Average cost per worker due to physical inactivity	$8.82		(1.21) * (4)	$22,583
				Total	$119,442

4.3.3 Benefits to Transit Agency

4.3.3.1 Fare Box Collection All these benefits are public related. Transit-fare revenues should also be considered as a direct benefit to the transit agency and should be deducted from the operation and maintenance costs. Based on information from BJCTA, the average transit-trip revenue in the Birmingham area is $0.70 (considering passes and discounts) in 2012 dollars. As a result of the proposed transit service, the benefits for transit use related to fare collection are $207,310 (2012 dollars) per year:

- Transit Agency Benefits
  = (Avg. Transit Trip Cost) * (Total Additional Transit Trips per Year)
  = ($0.70) * (296,157) = $207,310 per year

4.3.4 Costs

Costs associated with the project consist of capital costs, and operation and maintenance costs. All types of costs related to the implementation of the proposed transit plan have been evaluated below.

4.3.4.1 Capital Costs

4.3.4.1.1 Capital Costs for Buses Clark, *et al*. (2007) provided capital costs for buses according to fuel type and bus technology. Table 4-21 summarizes the overall capital costs associated with buses, including costs for vehicle procurement, refueling stations (CNG buses only), depot modifications, and emissions reduction equipment (diesel bus only). The American Public Transportation Association (APTA) (Dickens and Neff 2010) published the *2010 Public Transportation Fact Book*, from which the bus procurement costs have been identified and converted to 2012 dollars. Infrastructure costs for CNG buses include costs for depot modification and building the refueling station. According to the 2007 emissions standards, CNG buses meet the criteria without exhaust filtration. Therefore, emissions equipment costs only apply to diesel buses (ULSD and B20). For diesel hybrid buses, after-treatment (PM exhaust filtration) is considered an original equipment manufacturer (OEM) installation.

Table 4-21. Capital costs per bus (considering 100-bus fleet) (in 2012 dollars)

	CNG	ULSD	B20	Diesel Hybrid
Emissions Equipment	$0	$1,577	$1,577	$0
Depot Modification	$9,625	$0	$0	$1,540
Refueling Station	$22,000	$0	$0	$0
Vehicle Cost	$376,603	$351,680	$351,680	$584,766
Total	$408,228	$353,257	$353,257	$586,306

Source: Clark, *et al*. (2007)

Given the above mentioned consideration, total capital costs for the 9 CNG buses required to serve the demand according to the proposed transit plan was estimated as $3,674,052. It is:

- Capital Costs for Buses
  = (Capital Cost per Bus) * (Number of Bus Required for Service)
  = ($408,228) * (9) = $3,674,052 per year

4.3.4.1.2 Costs for Providing Shelters BJCTA provides two sizes of bus stop shelters—i.e. (a) large shelters measuring 18' x 5' and (b) small shelters measuring 9' x 5'—from which a community chooses (BJCTA). Shelters have been considered for every bus stop in internal routes (74 in total) and bus stops outbound from Fairfield for external routes (26+34=60 in total). Therefore, 134 shelters have been considered for the study. According to Highland Products Group, the cost for a 10'0" x 5'0" aluminum shelter with bench is about $5,047 (2012 dollars). Thus, the total costs for shelters for the proposed transit plan will be $676,298:

- Total Costs for Shelters
  = (Cost of a Shelter) * (Number of Shelters Required)
  = ($5,047) * (134) = $676,298

4.3.4.1.3 Costs for Local Station Construction RS Means (2008) provided a general cost estimate for constructing a local bus station for the Birmingham, AL region. The specification includes a one-story, 14-foot, union-built structure with a 5,000 ft^2 floor. Table 4-22 summarizes the details.

Table 4-22. Costs for transit station construction assuming decorative concrete block/steel frame (in 2012 dollars)

Cost Estimate (Union Labor)	% of Total	Cost Per Square Feet	Total Cost
Total	-	$83.90	$419,484
Contractor Fees (GC, Overhead, Profit)	25%	$20.98	$104,884
Architectural Fees	6%	$5.03	$25,168
User Fees	0%	$0	$0
Total Building Cost		$109.90	$549,484

Source: Reed Construction Data (2008)

4.3.4.1.4 Costs for Providing Sidewalks and Bike Lanes In addition to redesigning the bus service in the Fairfield community, TOD improvements are proposed, including the addition of sidewalks to increase accessibility, connectivity, and pedestrian safety. About 192,047 feet (approximately 36.5 miles) of sidewalk-less roadways have been identified in the Fairfield community. According to FHWA (Beneficial Designs, *et al*. 1999), the minimum sidewalk width is 5 feet in most design guidelines, which can accommodate pedestrian traffic in a residential area. According to Knoxville-Knox County Metropolitan Planning Commission, adding a sidewalk (including curb) to an existing roadway can cost $70 to $80 per linear foot. Thus, to execute the sidewalk addition plan proposed in the TOD of Fairfield, a total of $26.89 million would be needed.

- Total Costs for Sidewalks
  = (Cost of Sidewalk Construction per Linear Foot) * (Length of roadways Requires Sidewalk) * (Both Sides)

  = ($70) * (192,047) * (2) = $26,886,580

Bike lanes are also proposed for better accessibility and connectivity. Because we assume shared roadways, the bike lanes are on-street and the costs for implementing bike lanes are not considered.

4.3.4.1.5 Costs for Purchasing Land A 20,000-square foot area is considered for the construction of transit station and parking. According to a commercial real estate website, the land in Fairfield is valued around $3.05 per square foot (Romano). So the total land value for the local station is about $61,000:

- Costs for Purchasing Land
  = (Land Value per Square Feet) * (Area Required for Local Station)
  = ($3.05) * (20,000) = $61,000

4.3.4.2 Operation and Maintenance Costs

4.3.4.2.1 Operation and Maintenance Costs for Buses Clark, *et al*. (2007) provides information on bus operation and maintenance costs for various bus types. Such costs include compression electricity (CNG only), facility maintenance, propulsion-related system maintenance, battery replacement (hybrid only), and fuel consumption. The costs were converted to 2012 dollars and summarized in Table 4-23. The table excludes the fuel price, which has been quantified separately. The total operation and maintenance costs for the bus fleet needed to serve the transit needs of Fairfield under the proposed plan considering seven full-time (five full-time and four half-time) operating buses is $816,382 annually:

- Total Operation and Maintenance Costs
  = (Annual Operation and Maintenance Cost per Bus) * (Number of Bus Required for Service)
  = ($116,626) * (7) = $816,382 per year

Table 4-23. Annual operation and maintenance costs per bus excluding fuel costs (considering 12 years, 100-bus fleet) (in 2012 dollars)

	CNG	ULSD	B20	Diesel Hybrid
Compression Electricity	$20,903	$0	$0	$0
Facility Maintenance	$26,876	$22,795	$23,143	$19,217
Propulsion-related	$68,847	$73,033	$68,977	$69,948
System Maintenance	$0	$0	$0	$74,250
Total	$116,626	$95,829	$92,120	$163,415

Source: Clark, *et al*. (2007)

4.3.4.2.2 Annual Fuel Costs The fuel cost for CNG buses has been calculated from the product of national annual average mileage, estimated fuel economy, and predicted fuel price. Clark, *et al*. (2007) predicted fuel prices in 2007 dollars (see Figure 4-1). CNG price data are converted to the diesel gallon (energy) equivalent (DGE). One DGE of CNG is equivalent to about 126 cubic feet of CNG. Figure 4-2 shows the estimated fuel economy at national annual average speed of 12.72 mph adjusted by 10% for idling and loading.

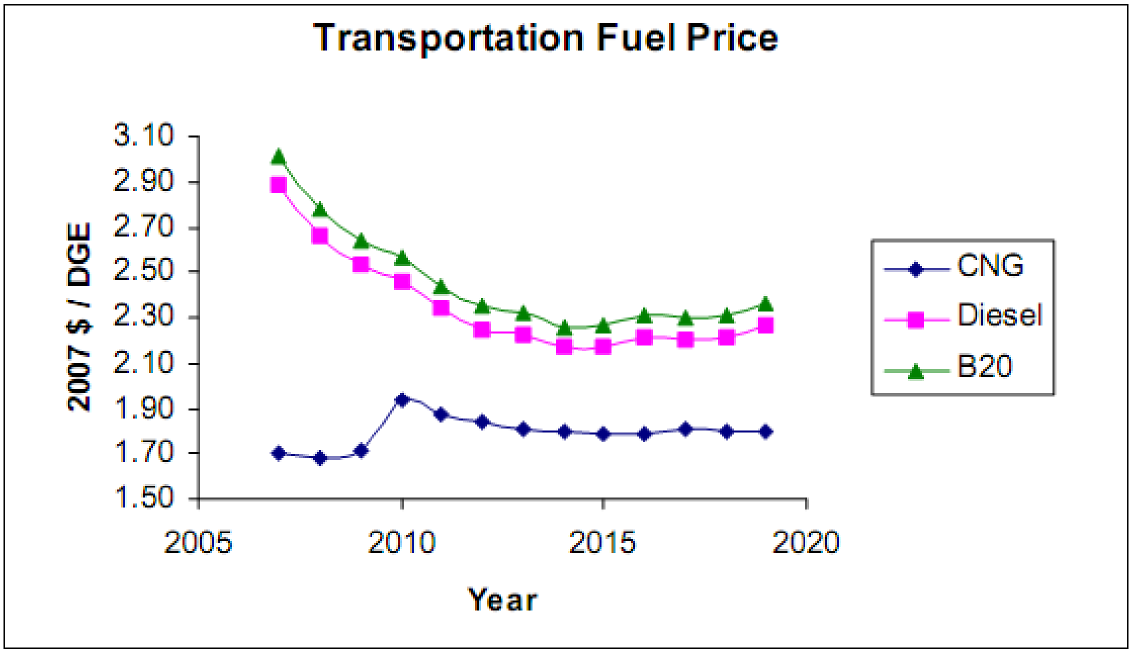

Figure 4-1. EIA diesel, CNG, and adjusted B20 price prediction (2007 –2019) (Clark, *et al*. 2007)

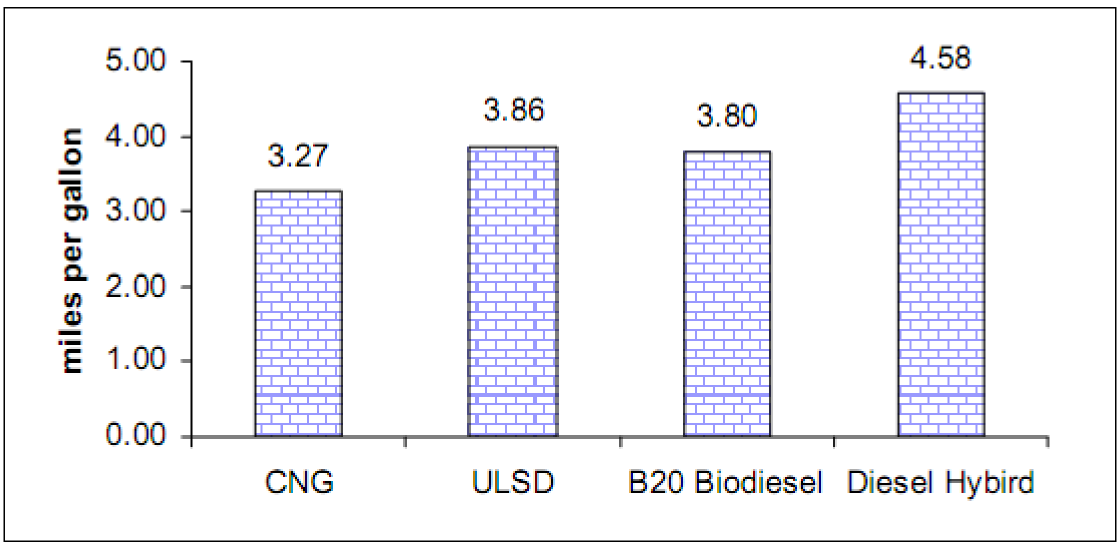

Figure 4-2. Estimated fuel economy (CNG bus on DGE base) (Clark, *et al*. 2007)

For 2012, the total fuel cost for 214,437 transit miles traveled per year or 65,578 DGE per year expected under the proposed transit plan is $137,058:

- Total DGE Required per Year = Annual Traveling Distance By Bus / Fuel Economy = 214,437 / 3.27 = 65,578 DGE per year
- Total Fuel Costs = (Cost of CNG per DGE) * (Total DGE Required per Year) * (Inflation Adjustment Factor) = ($1.90) * (65,578) * (1.10) = $137,058 per year

4.3.4.2.3 Personnel and Office Costs According to BJCTA's 2008 audit report, the organization's operating expenses for personnel and office requirements for 2008 (adjusted to 2012 dollars) are shown in Table 4-24. There are 300 employees working for BJCTA. It is estimated that 18 employees are needed to carry out the duties resulting from the proposed transit plan, including seven full-time bus drivers, two maintenance personnel, two janitors, two security personnel, and five office personnel.

Table 4-24. 2008 BJCTA personnel and office expenses (in 2012 dollars)

Categories	Total Amount
Salaries	$11,052,564
Health insurance and medical services	$2,312,003
Retirement and pension expenses	$1,869,712
Employment taxes	$828,685
Workers' compensation insurance	$361,655
Life insurance	$70,941
Janitorial and building supplies	$122,765
Temporary labor	$277,068
Uniforms	$104,481
Printing and copying	$92,701
Computers and software costs	$65,175
Security services	$184,369
Insurance	$1,636,254
Utilities	$507,866
Total	$19,486,239

Source: BJCTA (2008)

This corresponds to personnel and office cost of approximately 6.00% of the total amount of BJCTA expenses, or a total of $1,169,175 per year. The calculations of such costs follows:

- Total Personnel and Office Costs for the Local Station
  = (Total Office Expenses) * (% of Total Expenses)
  = ($19,486,239) * (6.00%) = $1,169,175 per year

4.3.5 Negative Impacts of Transit

4.3.5.1 Consideration of Cost of Time Cost of time refers to the additional cost that transit users would be paying while using transit due to additional time spent on travel. It is to be subtracted from other user benefits as riding the bus typically takes longer than driving an automobile to the same destination. Table 4-25 shows the average travel time by mode of travel per passenger mile based on the literature (2006).

Table 4-25. Trip time by mode of travel (minutes per mile)

	Single Occupancy Vehicle	Taxi	High Occupancy Vehicle	Walking	Bicycle	Bus
Avg. Trip time (min/mi)	2.1	2.3	2.1	19.4	12.3	5.25

Source: Goldsmith, *et al*. (2006)

Goldsmith, *et al*. (2006) estimated that the time cost per passenger mile for travel by bus (in 2006 dollars) is $0.26 greater than that of travel by car. So for the case-study conditions considered, the additional cost for using transit would be $87,011 per year:

- Total Losses due to Excess Travel Time by Transit
  = (Excess Time Cost for Bus than that of Car) * (Inflation Adjustment) * (Total Additional Transit Trips per Year)
  = ($0.26) * (1.13) * (296,157) = $87,011 per year

4.3.5.2 Consideration of Noise Pollution Noise pollution caused by traffic is typically associated with old engines, engine acceleration, contact of tire and road surface, horns, braking, vehicle theft alarms, etc. and can be influenced by type of vehicle and tire, grade, engine condition, pavement type and condition, barriers, etc. (Litman 2009).

As automobiles have smaller engines and higher power-to-weight ratio than those of buses, buses produce on average 5 to 15 times more noise than automobiles, depending on conditions (Litman 2012). Table 4-26 provides the marginal cost of noise for automobiles and buses per VMT from a 10% increase in VMT on different types of roads in urbanized areas.

Table 4-26. Noise pollution costs per vehicle mile traveled with 10% increase in VMT (in 2012 dollars)

Vehicle Type	Interstate	Other Freeways	Principal Arterials	Minor Arterials	Collectors	Local Roads
Base Case						
Light-duty Autos	$0.0049	$0.0071	$0.0020	$0.0010	$0.0001	$0.0000
Buses	$0.0106	$0.0163	$0.0120	$0.0107	$0.0020	$0.0000
Low-Cost Case						
Light-duty Autos	$0.0002	$0.0003	$0.0001	$0.0000	$0.0000	$0.0000
Buses	$0.0006	$0.0010	$0.0006	$0.0004	$0.0000	$0.0000
High-Cost Case						
Light-duty Autos	$0.0670	$0.0936	$0.0271	$0.0156	$0.0101	$0.0007
Buses	$0.1439	$0.2148	$0.1648	$0.1759	$0.1804	$0.0214

Source: Delucchi and Hsu (1998)

As part of the case study, principal arterials have been selected for the calculation of benefits from reduced noise pollution due to implementation of a new transit system. Minor arterials values have been considered for the internal route whereas principal arterial values have been considered for external routes. The noise related community costs are as follows:

- Community Costs due to Noise Pollution
  = (Noise Pollution Cost per VMT for Buses) * (Total Transit Travel Distance per Year) - (Noise Pollution Cost per VMT for Automobiles) * (Avg. Automobile Travel Distance per Day) * (Total Displaced Automobile Trips per Year)

= ($0.0120) * [(11.18)* (2) * (12) * (261) + (10.88) * (2) * (8) * (261)] - ($0.0020) * (13.70) * [(2) * (12) * (261) + (2) * (8) * (261)] + ($0.0107) * [(9.3) * (2) * (17) * (313)] - ($0.0010) * (13.70) * [(2) * (17) * (313)] = $2,021 per year

4.4 Benefit-Cost Ratio

Table 4-27 identifies the total benefits and costs associated with the Fairfield transit service improvement case study. Based on the study assumptions the total annual benefits have been calculated as $10,459,030 and the total costs as $34,059,061 for the base year 2012. Table 4-28 provides the annual costs and benefits related to the project. The total-fare value is increased at a rate of 1% per year, which is in line with a 1.01 CPI for monetary inflation observed from 2011 to 2012.

The transit agency yearly operation and maintenance costs are converted for each year up to year 2024 assuming a 1% increase (i.e. 1.01 CPI). Similarly, the total benefits are also converted until 2024. For 2010, the US internal rate of return (IRR) was 2.4%, according to the World Bank. . The cash flows for 12 years (i.e. operation and maintenance, total-fare collection benefits, and total benefits) have been converted to a net present value (NPV) for 2012.

The net benefit-cost (B/C) ratio for 2012 (base year) is equal to the total benefits (NPV) from 2013 to 2024 divided by the sum of capital costs at 2012 and total yearly expenses (includes operation and maintenance costs and negative impacts of transit) from 2013 to 2024 (NPV). Table 4-29 provides the benefit-cost ratio for the base year 2012 and the 12 years following, until 2024. A B/C ratio of 2.05 is found for the proposed transit implementation plan, or for every $1 dollar of investment the proposed project is expected to generate $2.05 in return.

4.5 Sensitivity Analysis

One of the assumptions of this case study is that the extended and redesigned transit service in the Fairfield community and other supporting improvements will result into a 10% shift to transit from automobile use for the impacted zones. To evaluate the potential return of the investment given a lower or higher modal shift to transit, a sensitivity analysis is performed.

In general, a sensitivity analysis identifies the parameters as the key drivers of a model’s results and helps understand the performance of the scheme if the parameters change. For the case study, a sensitivity analysis has been performed for 12 years to identify the possible outcome (in terms of net B/C ratio for 2012) for a 5%, 10%, 15%, and 20% ridership shift from automobile to transit.

The same procedure that was implemented earlier for a 10% shift is repeated for each of the other cases (i.e. 5%, 15%, and 20%). Appendix B includes detailed calculations, Table 4-30 provides summary results, and Figure 4-3 displays the benefit-cost ratios for different automobile travel shifts to transit for easy reference.

Table 4-27. Total benefits and costs associated with the proposed transit implementation plan for base year 2012 (in 2012 dollars)

Benefits			Costs		
	Benefits	**%Total**		**Costs**	**%Total**
Economy related Benefits			**Capital Costs**		
User Benefits			Capital Costs for Buses	$3,674,052	10.79%
Vehicle Owning and Operating Cost Savings	$5,310,688	50.78%	Costs for Providing Shelters	$676,298	1.99%
Avoided Chauffeuring Costs Savings	$2,655,353	25.39%	Costs for Local Station Construction	$549,484	1.61%
Traffic Accident Cost Savings for Users	$9,667	0.09%	Costs for Providing Sidewalks	$26,886,580	78.94%
Parking Cost Savings	$92,631	0.89%	Costs for Purchasing Land	$61,000	0.18%
Social and Community Benefits			**Total Capital Costs**	**$31,847,414**	**93.51%**
Use of Transit	$119,450	1.14%	Operation and Maintenance Costs		
Traffic Services Savings	$51,495	0.49%	Operation and Maintenance Costs for Buses	$816,382	2.40%
Traffic Congestion	$78,075	0.75%	Annual Fuel Costs	$137,058	0.40%
Parking	$277,893	2.66%	Personnel and Office Costs	$1,169,175	3.43%
Traffic Accident Cost Savings	$19,334	0.18%	**Total O& M Costs**	**$2,122,615**	**6.23%**
Air Pollution Cost Savings	$14,798	0.14%	Negative Impacts of Transit		
Option Value	$11,117	0.11%	Consideration of Cost of Time	$87,011	0.26%
Total Economy Related Benefits	**$8,640,501**	**82.61%**	Consideration of Noise Pollution	$2,021	0.01%
Health related Benefits			**Total Negative Impacts of Transit**	**$89,032**	**0.26%**
User Benefits					
Traffic Accident Cost Savings	$64,266	0.61%			
Pain and Suffering Cost Savings	$267,893	2.56%			
Social and Community Benefits					
Traffic Accident Cost Savings	$128,532	1.23%			
Air Pollution Cost Savings	$55,090	0.53%			
Public Health	$1,095,438	10.47%			
Total Health Related Benefits	**$1,611,219**	**15.41%**			
Fare-box Collection	**$207,310**	**1.98%**			
Total Benefits	**$10,459,030**	**100.00%**	**Total Costs**	**$34,059,061**	**100.00%**

Table 4-28. Annual costs and benefits (2012–2024)

Year	Capital Costs	Operation and Maintenance Costs	Negative Impacts of Transit	Total Yearly Expenses	Total Benefits
2012	$31,847,414	$2,122,615	$89,032	$2,211,647	$10,459,030
2013	0	$2,143,841	$89,922	$2,233,763	$10,563,620
2014	0	$2,165,280	$90,822	$2,256,101	$10,669,257
2015	0	$2,186,932	$91,730	$2,278,662	$10,775,949
2016	0	$2,208,802	$92,647	$2,301,449	$10,883,709
2017	0	$2,230,890	$93,574	$2,324,463	$10,992,546
2018	0	$2,253,199	$94,509	$2,347,708	$11,102,471
2019	0	$2,275,731	$95,454	$2,371,185	$11,213,496
2020	0	$2,298,488	$96,409	$2,394,897	$11,325,631
2021	0	$2,321,473	$97,373	$2,418,846	$11,438,887
2022	0	$2,344,687	$98,347	$2,443,034	$11,553,276
2023	0	$2,368,134	$99,330	$2,467,465	$11,668,809
2024	0	$2,391,816	$100,323	$2,492,139	$11,785,497

Table 4-29. Benefit-cost ratio for base year 2012 (in 2012 dollars)

	Net Present Value (NPV)
Capital Costs	$31,847,414
Total Yearly Expenses	$24,295,539
Net Costs	$56,142,953
Net Project Public Benefits	$114,895,267
Net Benefit-Cost Ratio	2.05

Table 4-30. Benefit-cost ratio for base year 2012 for different automobile trips shift to transit (in 2012 dollars)

	5% Shift	10% Shift	15% Shift	20% Shift
Capital Costs	$31,030,958	$31,847,414	$33,072,098	$34,705,010
Total Yearly Expenses	$21,494,998	$24,295,539	$29,090,719	$33,885,855
Net Costs	$52,525,956	$56,142,953	$62,162,817	$68,590,865
Net Project Public Benefits	$57,506,613	$114,895,267	$172,277,143	$229,644,012
Net Benefit-Cost Ratio	1.09	2.05	2.77	3.35

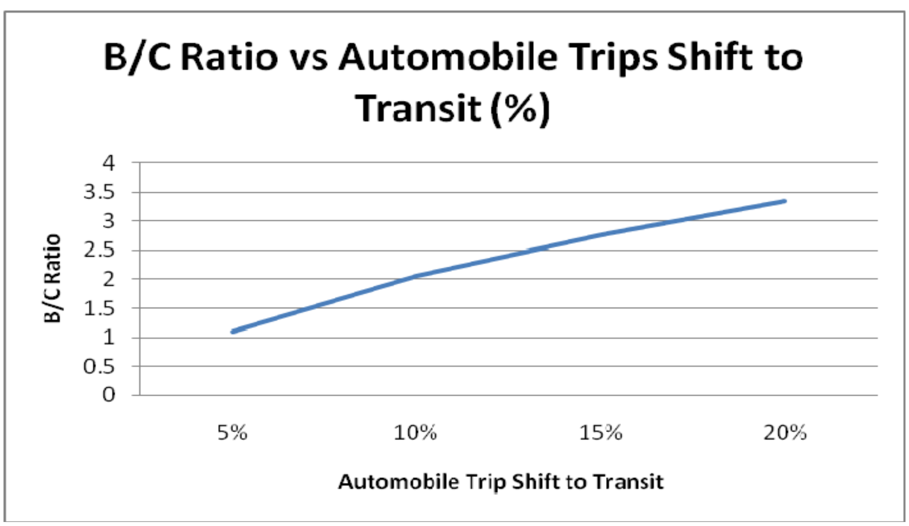

Figure 4-3. B/C ratio corresponding to different transit market share increments

It can be seen that the net benefit-cost ratio for 2012 for 5% through 20% automobile travel shifts to transit ranges from 1.09 to 3.35 respectively. The results confirm that the transit investment shows benefits even for modest mode choice changes that become more substantial as the shift toward transit increases.

Section 5
Conclusion and Recommendations

5.1 Introduction

The recent interest in smart growth, livable communities, and sustainability creates new opportunities for adoption, expansion, and enhancement of transit services in rural and urban communities across the U.S. Still, implementation of transit options requires buy-in from decision makers and the public, which in turn depends heavily on the clear documentation of costs and benefits expected from the investment in the short- and long-term.

This project has identified and summarized analytical methods appropriate for estimating transit's economic impacts as they relate to users, the transit agency, and the local community. Using inputs from earlier studies, national or regional data, and available methods, the study has quantified both health and economic impacts of transit integration (transit-oriented development) in a complete-street environment for a community in Alabama.

A major contribution of this study is the definition and use of appropriate TOD measures that show how well transit systems meet the needs of people in the communities they serve in terms of minimizing the cost associated with automobile use. Moreover, the methods presented and results obtained from the work presented in this project are expected to assist community planners, decision makers, and the public to better understand and appreciate the many positive safety, health, social, environmental, and economic impacts from integration of transit in complete-streets context and help promote adoption of transit investment in the future.

5.2 Project Findings

The project identified numerous benefits gained by the implementation of a new transit system and has identified engineering improvements that will enhance accessibility and increase ridership and user satisfaction. Among other factors, improvements in air quality, enhanced opportunity and access to medical facilities, reduction in traffic accidents and associated costs, savings related to vehicle owning and operating costs, traffic services savings, and traffic congestion reduction and associated benefits provide direct and indirect benefits to community and users.

A case study was undertaken to demonstrate the magnitude of such benefits based on data from a community on the outskirts of Birmingham, AL. The total benefits from the project have been projected out 12 years assuming implementation of an enhanced transit service plan that leads to 10% automobile user shift to transit for certain employment zones. From the origin-destination trip table (total 999 TAZs) provided by RPCGB, there are 71,144 total automobile trips in and out of Fairfield each day. The transit system will replace 1,057 (667 external + 390 internal) trips per day due to the 10% automobile trips (to certain work zones) shift to transit, which is 1.49% of the total trips in and out of Fairfield to all the 999 TAZs. The associated operation and maintenance costs have also been accounted for and projected out 12 years. In addition, further engineering improvements were considered, including addition of sidewalks throughout the community, and those costs were added to the total project cost. Overall, the benefit-cost ratio for the project has been calculated as 2.05, showing a good return for the investment should the proposed plan be adopted.

Moreover, a sensitivity analysis was undertaken to consider the correlation between modal shift toward transit and B/C ratios. An almost linear relationship between the B/C ratio and percentage ridership shift from automobile to transit was found.

Sidewalks have been considered for all the roadways without sidewalks to increase Fairfield's walkability. It would cost about $26.9 million to implement those sidewalks, a significant portion of the overall proposed project cost. However, sidewalk implementation is not a feature solely related to transit improvement but rather an improvement that promotes livability, improves the quality of life of local residents, and supports other community plans by local or state government to improve the lives of Fairfield residents.

5.3 Limitations and Recommendations

The project has identified health and economic benefits that a community can expect from 5%, 10%, 15%, and 20% trip shifts from automobile to transit market. A model to predict the anticipated shift from automobile to transit, taking into account socioeconomic conditions, could be beneficial.

Data from earlier studies and national or regional sources, as well as available methods, were used to calculate the benefits and costs associated with the project. Even though these values are cited in the literature, sometimes they are subjective and can be location and community dependent. Future studies should be carried out to better reflect Alabama's conditions. Moreover, there are other benefits that can be achieved from the implementation of the transit plan, such as taxi-fare savings, social safety nets, reductions in barriers, reduced water pollution, improved land use, etc. that are not quantified in this project.

There might be other impacts of the transit investment in Fairfield that were not considered, such as the creation of private-sector jobs and worker incomes in the local economy. Transit employees, local fuel-distribution businesses, and local construction contractors involved in constructing transit stations and setting up bus stops spend their earnings in the local market for different purposes, such as utilities, wages, living expenses, etc. Economic development benefits resulting from TOD have been observed in other studies and should be accounted for as part of a comprehensive TOD impacts assessment study.

Over the years, Fairfield's population growth has slowed, which may impact transit demand and operation. Future reduction in population may lead to reduction in need for transit service. Yet an improvement in transit service and accessibility to jobs and services as proposed in this study may improve the image of the community and increase the attractiveness of the community to businesses and current and future residents, thus leading to higher population growth. A follow-up study should consider population growth and other socioeconomic factors of the community in an attempt to better plan for transit needs in the future.

While some insight was gained on the implementation of a new transit system in this study, future research could focus on connecting the study with the RPCGB plan for a regional transit network, which can provide increased benefits for the local community and the region.

Section 6
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Appendix A

Table A-1. Transit Route 41 schedule (BJCTA)

41 FAIRFIELD
9/08

WEEKDAY

OUTBOUND						INBOUND				
CENTRAL STATION	BAPTIST MED CENTER PRINCETON	BESSEMER RD & AVENTUE W	FAIRFIELD POST OFFICE	KMART SHOPPING CENTER	WESTERN HILLS MALL	WESTERN HILLS MALL	FAIRFIELD POST OFFICE	BESSEMER RD & AVENUE W	BAPTIST MED CENTER PRINCE-TON	CENTRAL STATION
—	—	—	—	—	—	503	530	536	547	600
515	535	544	553	—	603	609	624	635	644	657
615	635	644	653	—	700	706	721	732	741	754
—	—	—	711	—	—	—	—	754	803	816
700	720	729	738	755	802	808	823	834	843	856
758	818	827	836	853	900	906	921	932	941	956
900	920	929	938	955	1002	1008	1023	1034	1043	1056
1000	1020	1029	1038	1055	1102	1108	1123	1134	1143	1156
1100	1120	1129	1138	1155	1202	1208	1223	1234	1243	1256
1200	1220	1229	1238	1255	102	108	123	134	143	156
1258	118	127	136	153	200	206	221	232	241	256
200	220	229	238	255	302	308	323	334	343	356
—	—	—	—	—	—	—	345	356	405	418
—	—	—	313	—	—	—	—	—	—	412
300	320	329	338	355	402	408	423	434	443	456
400	420	429	438	455	502	508	523	534	543	556
500	520	529	538	555	602	608	623	634	643	656
558	618	627	636	653	700	706	721	732	741	756
700	720	729	738	755	802	808	823	834	843	856
900	920	929	938	955	1002	—	—	—	—	—

SATURDAY

OUTBOUND						INBOUND				
CENTRAL STATION	BAPTIST MED CENTER PRINCETON	BESSEMER RD & AVENTUE W	FAIRFIELD POST OFFICE	KMART SHOPPING CENTER	WESTERN HILLS MALL	WESTERN HILLS MALL	FAIRFIELD POST OFFICE	BESSEMER RD & AVENUE W	BAPTIST MED CENTER PRINCETON	CENTRAL STATION
—	—	—	—	—	—	605	620	631	640	653
700	720	729	738	755	802	805	820	831	840	853
800	820	829	838	855	902	905	920	931	940	953
900	920	929	938	955	1002	1005	1020	1031	1040	1053
1000	1020	1029	1038	1055	1102	1105	1120	1131	1140	1153
1100	1120	1129	1138	1155	1202	1205	1220	1231	1240	1253
1200	1220	1229	1238	1255	102	105	120	131	140	153
100	120	129	138	155	202	205	220	231	240	253
200	220	229	238	255	302	305	320	331	340	353
300	320	329	338	355	402	405	420	431	440	453
400	420	429	438	455	502	505	520	531	540	553
500	520	529	538	555	602	605	620	631	640	653
600	620	629	638	655	702	705	720	731	740	753
700	720	729	738	755	802	805	820	831	840	853
800	820	829	838	855	902	—	—	—	—	—
900	920	929	938	955	1002	—	—	—	—	—

Appendix B

B.1 5% Ridership Shift from Automobile to Transit

Table B-1. Future transit use given 5% automobile trips shift to transit

TAZ	Total Trips	5% Shift to Transit	Transit Trips	Present Transit Use	Future Transit Use	Comments
444	3,864	194	334	195	529	External Trips
664	2,796	140				
666						
Internal	3,901	195	195	106	301	Internal Trips

Table B-2. Roundtrip travel time given 5% automobile trips shift to transit

TAZ	Route Length (miles)	Passengers per hour per direction	Number of Stops (Major and Minor)	Headway (hr)	Roundtrip Travel Time (mins)	Trips Required (per hr)
444	11.18	194/(2*2)=49	26	0.5	83	49/40=2
664	10.88	140/(2*2)=35	34	1	84	34/40=1
666						
Internal		(195+106)/(17*2)=9				
Internal (Clockwise)	9.3	9	37	1	34	9/40=1
Internal (Counter Clockwise)	9.3	9	37	1	34	9/40=1

Three buses are required for route 444 and two buses are required for route 664 to serve the work trips.

Total Additional Transit Trips = (194+140) * (261) + (195) * (313) = 148,209 trips per year

Annual Bus Trips = (2) * (17) * (313) + (2) * (8) * (261) + (2) * (4) * (261) = 16,906 trips per year

Annual Miles Traveled by Bus = (9.3) * (2) * (17) * (313) + (11.18)* (2) * (8) * (261) + (10.88) * (2) * (4) * (261) = 168,376 miles per year

Table B-3. Bus schedule for external and internal routes given 5% automobile trips shift to transit

External Route 444								
Bus No.	Morning Schedule (AM)				Evening Schedule (PM)			
	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield
1	6:00	6:40	6:43	7:23	4:00	4:40	4:43	5:23
2	6:30	7:10	7:13	7:53	4:30	5:10	5:13	5:53
3	7:00	7:40	7:43	8:23	5:00	5:40	5:43	6:23
1	7:30	8:10	8:13	8:53	5:30	6:10	6:13	6:53
External Route 664								
Bus No.	Morning Schedule (AM)				Evening Schedule (PM)			
	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield
1	6:00	6:40	6:43	7:24	4:00	4:40	4:43	5:24
2	7:00	7:40	7:43	8:24	5:00	5:40	5:43	6:24
Internal Route								
Operates from 5 am to 10 pm on a 30-minute schedule								

Table B-4. Total benefits and costs associated with the proposed transit implementation plan for base year 2012 given 5% automobile trips shift to transit (2012 Dollar Value)

Benefits			**Costs**		
	Benefits	**%Total**		**Costs**	**%Total**
Economy related Benefits			**Capital Costs**		
User Benefits			Capital Costs for Buses	$2,857,596	8.66%
Vehicle Owning and Operating Cost Savings	$2,657,684	50.77%	Costs for Providing Shelters	$676,298	2.05%
Avoided Chauffeuring Costs Savings	$1,328,842	25.38%	Costs for Local Station Construction	$549,484	1.67%
Traffic Accident Cost Savings for Users	$4,801	0.09%	Costs for Providing Sidewalks	$26,886,580	81.50%
Parking Cost Savings	$46,413	0.89%	Costs for Purchasing Land	$61,000	0.18%
Social and Community Benefits			Total Capital Costs	$31,030,958	94.07%
Use of Transit	$59,778	1.14%	**Operation and Maintenance Costs**		
Traffic Services Savings	$24,952	0.48%	Operation and Maintenance Costs for Buses	$699,756	2.12%
Traffic Congestion	$36,348	0.69%	Annual Fuel Costs	$107,616	0.33%
Parking	$139,239	2.66%	Personnel and Office Costs	$1,104,220	3.35%
Traffic Accident Cost Savings	$9,602	0.18%	Total O& M Costs	$1,911,593	5.79%
Air Pollution Cost Savings	$7,344	0.14%	**Negative Impacts of Transit**		
Option Value	$11,117	0.21%	Consideration of Cost of Time	$43,544	0.13%
Total Economy Related Benefits	$4,326,120	82.64%	Consideration of Noise Pollution	$1,574	0.00%
Health related Benefits			Total Negative Impacts of Transit	$45,118	0.14%
User Benefits					
Traffic Accident Cost Savings	$31,917	0.61%			
Pain and Suffering Cost Savings	$133,047	2.54%			
Social and Community Benefits					
Traffic Accident Cost Savings	$63,835	1.22%			
Air Pollution Cost Savings	$27,196	0.52%			
Public Health	$549,023	10.49%			
Total Health Related Benefits	$805,018	15.38%			
Fare-box Collection	$103,746	1.98%			
Total Benefits	$5,234,884	100.00%	Total Costs	$32,987,669	100.00%

Table B-5. Annual costs and benefits from 2012-2024 given 5% automobile trips shift to transit

Year	Capital Costs	Operation and Maintenance Costs	Negative Impacts of Transit	Total Yearly Expenses	Total Benefits
2012	$31,030,958	$1,911,593	$45,118	$1,956,711	$5,234,884
2013	0	$1,930,709	$45,569	$1,976,278	$5,287,233
2014	0	$1,950,016	$46,025	$1,996,041	$5,340,105
2015	0	$1,969,516	$46,485	$2,016,001	$5,393,506
2016	0	$1,989,211	$46,950	$2,036,161	$5,447,441
2017	0	$2,009,103	$47,419	$2,056,523	$5,501,916
2018	0	$2,029,194	$47,894	$2,077,088	$5,556,935
2019	0	$2,049,486	$48,373	$2,097,859	$5,612,504
2020	0	$2,069,981	$48,856	$2,118,838	$5,668,629
2021	0	$2,090,681	$49,345	$2,140,026	$5,725,316
2022	0	$2,111,588	$49,838	$2,161,426	$5,782,569
2023	0	$2,132,704	$50,337	$2,183,041	$5,840,394
2024	0	$2,154,031	$50,840	$2,204,871	$5,898,798

B.2 15% Ridership Shift from Automobile to Transit

Table B-6. Future transit use given 15% automobile trips shift to transit

TAZ	Total Trips	15% Shift to Transit	Transit Trips	Present Transit Use	Future Transit Use	Comments
444	3,864	580	999	195	1,194	External Trips
664	2,796	419				
666						
Internal	3,901	586	586	106	692	Internal Trips

Table B-7. Roundtrip travel time given 15% automobile trips shift to transit

TAZ	Route Length (miles)	Passengers per hour per direction	Number of Stops (Major and Minor)	Headway (hr)	Roundtrip Travel Time (mins)	Trips Required (per hr)
444	11.18	580/(2*2)=145	26	0.25	88	145/40=4
664	10.88	419/(2*2)=105	34	0.33	87	105/40=3
666						
Internal		692/(17*2)=21				
Internal (Clockwise)	9.3	21	37	1	36	18/40=1
Internal (Counter Clockwise)	9.3	21	37	1	36	18/40=1

Six buses are required for route 444 and four buses are required for route 664 to serve the work trips.

Total Additional Transit Trips = (580 + 419) * (261) + (586) * (313) = 444,157 trips per year

Annual Bus Trips = (2) * (17) * (313) + (2) * (16) * (261) + (2) * (12) * (261) = 25,258 trips per year

Annual Miles Traveled by Bus = (9.3) * (2) * (17) * (313) + (11.18) * (2) * (16) * (261) + (10.88) * (2) * (12) * (261) = 260,499 miles per year

Table B-8. Bus schedule for external and internal routes given 15% automobile trips shift to transit

External Route 444								
Bus No.	**Morning Schedule (AM)**				**Evening Schedule (PM)**			
	Leaving Fairfield	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**	**Leaving Fairfield**	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**
1	6:00	6:41	6:44	7:26	4:00	4:41	4:44	5:26
2	6:15	6:56	6:59	7:41	4:15	4:56	4:59	5:41
3	6:30	7:11	7:14	7:56	4:30	5:11	5:14	5:56
4	6:45	7:26	7:29	8:11	4:45	5:26	5:29	6:11
5	7:00	7:41	7:44	8:26	5:00	5:41	5:44	6:26
6	7:15	7:56	7:59	8:41	5:15	5:56	5:59	6:41
1	7:30	8:11	8:14	8:56	5:30	6:11	6:14	6:56
2	7:45	8:26	8:29	9:11	5:45	6:26	6:29	7:11
External Route 664								
Bus No.	**Morning Schedule (AM)**				**Evening Schedule (PM)**			
	Leaving Fairfield	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**	**Leaving Fairfield**	**Reaching External Zone**	**Leaving External Zone**	**Reaching Fairfield**
1	6:00	6:40	6:43	7:24	4:00	4:40	4:43	5:24
2	6:20	7:00	7:03	7:44	4:20	5:00	5:03	5:44
3	6:40	7:20	7:23	8:04	4:40	5:20	5:23	6:04
4	7:00	7:40	7:43	8:24	5:00	5:40	5:43	6:24
1	7:30	8:10	8:13	8:54	5:30	6:10	6:13	6:54
2	7:50	8:30	8:33	9:14	5:50	6:30	6:33	7:14
Internal Route								
Operates from 5 am to 10 pm on a 30-minute schedule								

Table B-9. Total benefits and costs associated with the proposed transit implementation plan for base year 2012 given 15% automobile trips shift to transit (in 2012 dollars)

Benefits		
	Benefits	**%Total**
Economy related Benefits		
User Benefits		
Vehicle Owning and Operating Cost Savings	$7,964,623	50.79%
Avoided Chauffeuring Costs Savings	$3,982,312	25.39%
Traffic Accident Cost Savings for Users	$14,468	0.09%
Parking Cost Savings	$138,881	0.89%
Social and Community Benefits		
Use of Transit	$179,143	1.14%
Traffic Services Savings	$78,048	0.50%
Traffic Congestion	$119,817	0.76%
Parking	$416,642	2.66%
Traffic Accident Cost Savings	$28,936	0.18%
Air Pollution Cost Savings	$22,254	0.14%
Option Value	$11,117	0.07%
Total Economy Related Benefits	$12,956,241	82.62%
Health related Benefits		
User Benefits		
Traffic Accident Cost Savings	$96,183	0.61%
Pain and Suffering Cost Savings	$400,940	2.56%
Social and Community Benefits		
Traffic Accident Cost Savings	$192,367	1.23%
Air Pollution Cost Savings	$82,992	0.53%
Public Health	$1,642,926	10.48%
Total Health-Related Benefits	$2,415,408	15.40%
Fare-box Collection	$310,910	1.98%
Total Benefits	$15,682,559	100.00%

Costs		
	Costs	%Total
Capital Costs		
Capital Costs for Buses	$4,898,736	13.71%
Costs for Providing Shelters	$676,298	1.89%
Costs for Local Station Construction	$549,484	1.54%
Costs for Providing Sidewalks	$26,886,580	75.27%
Costs for Purchasing Land	$61,000	0.17%
Total Capital Costs	$33,072,098	92.59%
Operation and Maintenance Costs		
Operation and Maintenance Costs for Buses	$1,049,634	2.94%
Annual Fuel Costs	$166,496	0.47%
Personnel and Office Costs	$1,299,083	3.64%
Total O& M Costs	$2,515,213	7.04%
Negative Impacts of Transit		
Consideration of Cost of Time	$130,493	0.37%
Consideration of Noise Pollution	$2,451	0.01%
Total Negative Impacts of Transit	$132,944	0.37%
Total Costs	$35,720,255	100.00%

Table B-10. Annual costs and benefits from 2012-2024 given 15% automobile trips shift to transit

Year	Capital Costs	Operation and Maintenance Costs	Negative Impacts of Transit	Total Yearly Expenses	Total Benefits
2012	$33,072,098	$2,515,213	$132,944	$2,648,157	$15,682,559
2013	0	$2,540,365	$134,273	$2,674,639	$15,839,385
2014	0	$2,565,769	$135,616	$2,701,385	$15,997,778
2015	0	$2,591,426	$136,972	$2,728,399	$16,157,756
2016	0	$2,617,341	$138,342	$2,755,683	$16,319,334
2017	0	$2,643,514	$139,725	$2,783,240	$16,482,527
2018	0	$2,669,949	$141,123	$2,811,072	$16,647,352
2019	0	$2,696,649	$142,534	$2,839,183	$16,813,826
2020	0	$2,723,615	$143,959	$2,867,575	$16,981,964
2021	0	$2,750,851	$145,399	$2,896,250	$17,151,784
2022	0	$2,778,360	$146,853	$2,925,213	$17,323,302
2023	0	$2,806,144	$148,321	$2,954,465	$17,496,535
2024	0	$2,834,205	$149,805	$2,984,010	$17,671,500

B.3 20% Ridership Shift from Automobile to Transit

Table B-11. Future transit use given 20% automobile trips shift to transit

TAZ	Total Trips	20% Shift to Transit	Transit Trips	Present Transit Use	Future Transit Use	Comments
444	3,864	773	1,332	195	1,527	External Trips
664	2,796	559				
666						
Internal	3,901	781	781	106	887	Internal Trips

Table B-12. Roundtrip travel time given 20% automobile trips shift to transit

TAZ	Route Length (miles)	Passengers per hour per direction	Number of Stops (Major and Minor)	Headway (hr)	Roundtrip Travel Time (mins)	Trips Required (per hr)
444	11.18	773/(2*2)=194	26	0.167	88	194/40=5
664	10.88	559/(2*2)=140	34	0.25	87	140/40=4
666						
Internal		887/(17*2)=26				
Internal (Clockwise)	9.3	26	37	1	37	37/40=1
Internal (Counter Clockwise)	9.3	26	37	1	37	37/40=1

Eight buses are required for route 444 and six buses are required for route 664 to serve the work trips.

Total Additional Transit Trips = (773+559) * (261) + (781) * (313) = 592,105 trips per year

Annual Bus Trips = (2) * (17) * (313) + (2) * (20) * (261) + (2) * (16) * (261) = 29,434 trips per year

Annual Miles Traveled by Bus = (9.3) * (2) * (17) * (313) + (11.18) * (2) * (20) * (261) + (10.88) * (2) * (16) * (261) = 306,560 miles per year

Table B-13. Bus schedule for external and internal routes given 20% automobile trips shift to transit

External Route 444								
Bus No.	Morning Schedule (AM)				Evening Schedule (PM)			
	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield
1	6:00	6:41	6:44	7:25	4:00	4:41	4:44	5:25
2	6:10	6:51	6:54	7:35	4:10	4:51	4:54	5:35
3	6:20	7:01	7:04	7:45	4:20	5:01	5:04	5:45
4	6:30	7:11	7:14	8:55	4:30	5:11	5:14	5:55
5	6:40	7:21	7:24	8:05	4:40	5:21	5:24	6:05
6	6:50	7:31	7:34	8:15	4:50	5:31	5:34	6:15
7	7:00	7:41	7:44	8:25	5:00	5:41	5:44	6:25
8	7:10	7:51	7:54	8:35	5:10	5:51	5:54	6:35
1	7:30	8:11	8:14	8:55	5:30	6:11	6:14	6:55
2	7:50	8:31	8:34	9:15	5:50	6:31	6:34	7:15
External Route 664								
Bus No.	Morning Schedule (AM)				Evening Schedule (PM)			
	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield	Leaving Fairfield	Reaching External Zone	Leaving External Zone	Reaching Fairfield
1	6:00	6:40	6:43	7:24	4:00	4:40	4:43	5:24
2	6:15	6:55	6:58	7:39	4:15	4:55	4:58	5:39
3	6:30	7:10	7:13	7:54	4:30	5:10	5:13	5:54
4	6:45	7:25	7:28	8:09	4:45	5:25	5:28	6:09
5	7:00	7:40	7:43	8:24	5:00	5:40	5:43	6:24
6	7:15	7:55	7:58	8:39	5:15	5:55	5:58	6:39
1	7:30	8:10	8:13	8:54	5:30	6:10	6:13	6:54
2	7:45	8:25	8:28	9:09	5:45	6:25	6:28	7:09
Internal Route								
Operates from 5 am to 10 pm on a 30-minute schedule								

Table B-14. Total benefits and costs associated with the proposed transit implementation plan for base year 2012 given 20% automobile trips shift to transit (in 2012 dollars)

Benefits			Costs		
	Benefits	**%Total**		**Costs**	%Total
Economy related Benefits			**Capital Costs**		
User Benefits			Capital Costs for Buses	$6,531,648	17.28%
Vehicle Owning and Operating Cost Savings	$10,617,627	50.79%	Costs for Providing Shelters	$676,298	1.79%
Avoided Chauffeuring Costs Savings	$5,308,813	25.40%	Costs for Local Station Construction	$549,484	1.45%
Traffic Accident Cost Savings for Users	$19,269	0.09%	Costs for Providing Sidewalks	$26,886,580	71.15%
Parking Cost Savings	$185,294	0.89%	Cost for Purchasing Land	$61,000	0.16%
Social and Community Benefits			Total Capital Costs	$34,705,010	91.84%
Social Use of Transit	$238,816	1.14%	**Operation and Maintenance Costs**		
Traffic Services Savings	$104,591	0.50%	Operation and Maintenance Costs for Buses	$1,282,886	3.39%
Traffic Congestion	$161,543	0.77%	Annual Fuel Costs	$195,936	0.52%
Parking	$555,881	2.66%	Personnel and Office Costs	$1,428,991	3.78%
Traffic Accident Cost Savings	$38,538	0.18%	Total O& M Costs	$2,907,813	7.69%
Air Pollution Cost Savings	$29,707	0.14%	**Negative Impacts of Transits**		
Option Value	$11,117	0.05%	Consideration of Cost of Time	$173,960	0.46%
Total Economy Related Benefits	$17,271,196	82.62%	Consideration of Noise Pollution	$2,889	0.01%
Health Related Benefits			Total Negative Impacts of Transit	$176,850	0.47%
User Benefits					
Traffic Accident Cost Savings	$128,101	0.61%			
Pain and Suffering Cost Savings	$533,987	2.55%			
Social and Community Benefits					
Traffic Accident Cost Savings	$256,201	1.23%			
Air Pollution Cost Savings	$110,885	0.53%			
Public Health	$2,189,878	10.48%			
Total Health-Related Benefits	$3,219,052	15.40%			
Fare-box Collection	$414,474	1.98%			
Total Benefits	$20,904,722	100.00%	Total Costs	$37,789,673	100.00%

Table B-15. Annual costs and benefits from 2012-2024 given 20% automobile trips shift to transit

Year	Capital Costs	Operation and Maintenance Costs	Negative Impacts of Transit	Total Yearly Expenses	Total Benefits
2012	$34,705,010	$2,907,813	$176,850	$3,084,663	$20,904,722
2013	0	$2,936,891	$178,619	$3,115,510	$21,113,769
2014	0	$2,966,260	$180,405	$3,146,665	$21,324,907
2015	0	$2,995,923	$182,209	$3,178,131	$21,538,156
2016	0	$3,025,882	$184,031	$3,209,913	$21,753,538
2017	0	$3,056,141	$185,871	$3,242,012	$21,971,073
2018	0	$3,086,702	$187,730	$3,274,432	$22,190,784
2019	0	$3,117,569	$189,607	$3,307,176	$22,412,691
2020	0	$3,148,745	$191,503	$3,340,248	$22,636,818
2021	0	$3,180,232	$193,418	$3,373,650	$22,863,187
2022	0	$3,212,035	$195,352	$3,407,387	$23,091,818
2023	0	$3,244,155	$197,306	$3,441,461	$23,322,737
2024	0	$3,276,596	$199,279	$3,475,875	$23,555,964